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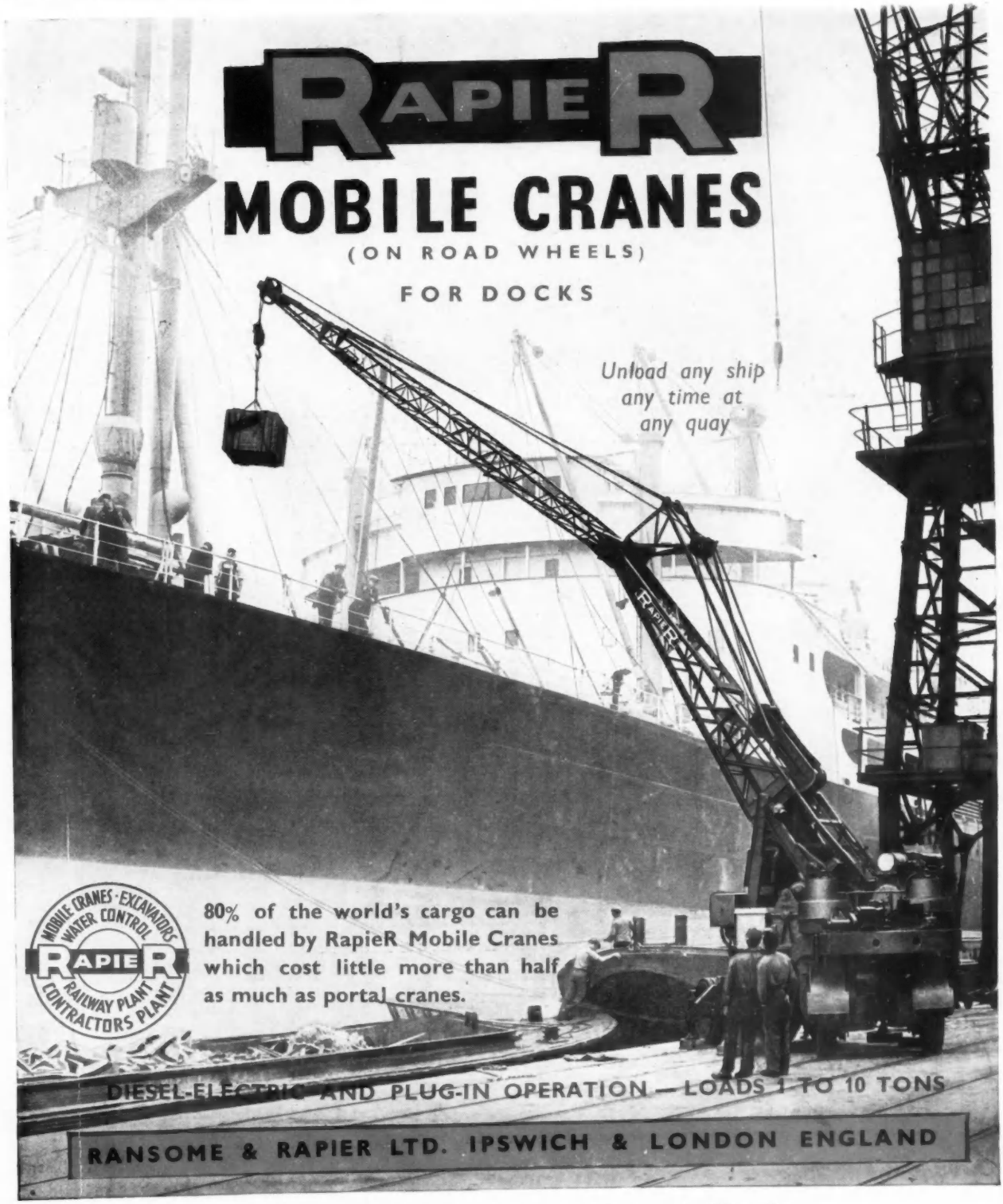
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Editorial Comments

The Port of Dakar.

It will be remembered that a description of the Port of Dakar formed the leading article in the February 1952 issue of this Journal. This reviewed the striking progress that had been made at Dakar during the last few decades, and gave an account of the modernisation and extension schemes then being carried out. We are now privileged to publish this month further particulars concerning the construction of Mole I, which is now substantially completed and the greater part of which is in service. We are indebted to Mons. M. Giraud, Engineer-in-Chief to the Port of Dakar for the technical details kindly supplied.

The special significance of Mole I is the unusual design of the sheds, and the layout of the quays for the handling of general cargo, both import and export.

There have been one or two instances in other ports, of multi-storey sheds with access to the upper floors provided by ramps for trucks and mobile cranes. A further example concerns the Port of Stockholm where a rebuilding scheme for the Stadsgard Harbour provides for quay space on two levels, with sheds of one or more storeys opposite each ship's berth, the second or upper quay area being at the first floor level of the sheds. Mole I at Dakar is, however, as far as we are aware, the first constructed example of its particular type, and it is interesting to learn that its general day to day operation is proving successful.

It will be at once apparent that the principles involved could provide a solution to many problems at ports where the space for quays and sheds is restricted and where road transport is increasing.

Sea and Air Transport.

The shipowners of Great Britain have always contended that air transport can be only complementary to sea transport because of the relatively large difference in load carrying capacity. Nevertheless they became aware during the war that sea transport would undoubtedly have to face the competition of aircraft in the case of certain travel and transport facilities hitherto given solely by ships. The General Council of British Shipping therefore produced a statement of policy, the aim of which was the establishment of a balance between air and sea services. As a result, in 1943 five shipping companies together with the four main-line railway groups of Great Britain formed plans for the post-war operation of overseas and internal air services.

These proposals did not find favour with the war-time Coalition Government. In 1945 it was announced that a Bill would be introduced providing for Commonwealth, Far East and North Atlantic air services to be operated by the B.O.A.C., and Latin-American services by a company operated by the Blue Star, P.S.N.C., Royal Mail, Booth and Lamport and Holt Steamship Lines, while the European and internal British services would be the responsibility of a company representative of various interests including shipping and railways.

After the war however, the whole situation was transformed when the transport services of Great Britain were nationalised. The shipping companies were not included in the scheduled air services then formed, and only now are some of them operating such services through the agency of independent companies.

Normally passengers and freight arriving at terminal air bases tranship there for a continuation of the journey by rail, road or air, or alternatively by sea. It is easy to visualise therefore the complementary nature that air travel bears to the other transport services. When such conditions become general and on an increased scale it would appear that the ideal arrangement would be for aeroplanes, seaplanes and shipping to be accommodated within a reasonable distance of each other.

Some aeronautical experts are of the opinion that the seaplane is destined eventually to supersede the aeroplane in long distance transport. It is suggested that the atomic-powered aircraft for such services would be so heavy that existing runways would need rebuilding at prohibitive cost. The flying boat would therefore provide an economic alternative. If this proves to be the case, many dock and harbour authorities may find themselves faced with the necessity of providing harbourage for seaplanes in sheltered water within the limits of their ports.

The increasing competition of air transport can no longer be ignored by shipping companies, and it is not surprising therefore that the leading lines are seeking to complement their sea transport activities by joining forces with air transport operators. The benefits to the community will be unquestioned provided that co-operation between operators, rather than the establishment of purely competitive and independent air services, can be assured by appropriate legislation.

Ship Fires in Port.

In the past few years there have been a number of disastrous fires on board ships in port resulting in the total loss or grave damage of the vessel and the spread of the fire to dockside sheds and warehouses which, without prompt measures by fire brigades, could have resulted in a widespread conflagration. Needless to say, courts of enquiry have been set up to enquire into the causes of these outbreaks of fire and to make recommendations for future safety precautions.

Elsewhere in this issue will be found an article on the salving of the " Empress of Canada " which was gutted by fire and sank, a total loss, in the Liverpool docks over a year ago. It should, however, be borne in mind that the liner was built before the Convention of 1948 laid down certain preventive constructional requirements and that consequently the findings of the Court of Enquiry cannot be wholly applied to vessels built subsequent to the Convention of 1948. No ship built under the Convention's recommendation has, fortunately, been tested by a major outbreak of fire. There is, therefore, little to prove that the requirements of the Convention are as suffiicent a safeguard as was intended. Only experience and study of ship fires can give an answer.

Structural design is not the only factor in the spread of fire on board ship for there remains the human factor. The head of the Hamburg Fire Department recently expressed the opinion that of the 200 fires which had occurred on board ships in that port since the war, 90 per cent. were due to carelessness. He instanced welding operations and faulty electrical equipment in the ship.

Fire fighting is more difficult in ships than on land, and there is always the grave risk that the weight of water pumped into the holds will cause the ship to heel over and sink, which in a dock or

Editorial Comments—continued

narrow channel could well obstruct the movement of other vessels.

Oil tankers present their own particular problem. It is the usual practice to segregate tankers from all other types of shipping using a port because of the risk of fire when discharging or loading these inflammable cargoes of oil and spirit. There still remains the risk of a fire on board a tanker spreading to the shore installations where large quantities of petroleum spirit may be stored. For dealing with this contingency, foam generators are generally installed at such berths in addition to the usual hose and water appliances.

It would appear that on the one hand shipowners will in future pay greater attention to fire prevention and the provision of fire-fighting equipment on board their ships, and that on the other hand dock and harbour authorities will provide themselves where necessary with more stringent regulations for the prevention of fire on board vessels moored alongside their quays.

Dockers' Welfare and Turn-round of Ships.

At a meeting of the Inland Transport Committee of the International Labour Organisation, held in Geneva recently, the question of the quicker turn-round of ships in port was considered in relation to the provision of increased welfare facilities for dock workers. The report presented to the meeting, which was attended by government, employers' and workers' delegates from 32 countries, noted that often ships spend more time in port than at sea. It went on to say, " The absence of good relations tends to lower productivity, and world trade requires keenness and efficiency in securing quick turn-round of ships. Slowness may be due not as much to lack of equipment as to the difficulty of ensuring the whole-hearted co-operation of workers concerned." The provision of welfare facilities, the report suggests, can contribute greatly to improving working conditions and thereby human and industrial relations.

Thirty years ago there was scarcely any reference to these matters, but in recent years a great many ports have shown a lively interest in the provision of welfare facilities, such as covered calling-on stands, canteens, and medical centres. The report suggests that welfare measures should be backed by a system of consultation between workers and employers, particularly where new mechanical equipment or incentive systems are introduced. With this latter suggestion we concur. With regard to the welfare facilities suggested we would point out that the National Dock Labour Board and the Port Authorities have already provided many such facilities in the ports of the United Kingdom, but how far these are accepted as part and parcel of the welfare age in which we live or as a serious contribution to the bettering of dockers' working conditions is difficult to assess.

Peterhead Harbour of Refuge.

An important stage in the construction of Peterhead harbour of refuge was reached last month when men engaged on the project made the last granite block as part of the foundation of the pierhead for the north arm of the breakwater. When construction began in 1886, it was estimated that the undertaking would be completed within 25 or 30 years, at a cost of £760,000, but today, 68 years later, the work still goes on, and it is expected that the scheme, when completed in about two years time, will have cost over £2 million. Divers work 90-ft. under water, clearing away sand and manœuvring into place cement blocks, weighing from 20 to 45 tons each.

The project was started when active work for Scotland's long-term convicts was being sought. At the outset the Treasury allowed an annual grant of £32,000, but in 1911 announced their intention of discontinuing the grant. Following strong local representations, however, the Treasury revoked their decision, and the south arm of the breakwater was completed in 1912. An immediate start was then made on the north arm at Keith Inch, on the opposite side of the south bay. For a number of years well-behaved convicts were employed, but subsequently the work slowed down as the number of convicts decreased. Two world wars also interrupted the work.

Several years ago an Admiralty committee visited Peterhead to ascertain the view of local public boards and other representatives on the most desired length of the north arm.

It took about a year to add 40-ft. to the huge piers that stretch their protecting arms across the bay, which affords a safe anchorage to coastwise shipping during gales.

The actual breakwater, which is 1,500-ft. in length, has now been completed, and the pierhead at the end of the north arm will be about 35-ft. above low water. Work has already begun on the last stage of the scheme, which is one of the largest marine constructional works attempted in Scotland, and the completion of the pierhead, which will depend on weather conditions, may take two or more years.

The scheme has not escaped criticism, and many Peterhead fishermen consider that the south arm should not have been built. They contend that this arm, which stands out against heavy seas, causes a backwash that can be felt 10 miles out to sea. They maintain that the worst storms come from the north-east, and that the north arm would give all the shelter needed.

Topical Notes

Reduction of Attendance Money Levy in Australia.

It was recently announced by the Prime Minister of Australia that the levy imposed by the Australian Stevedoring Industry Board on employers of waterside labour will be reduced from 11d. to 6d. per man-hour as from the first pay period in May. This levy provides attendance money for dockers for whom no work is available and is calculated on the number of man-hours worked. The reduction has been made possible by more stable employment reducing the incidence of attendance money payments.

The Australian Government expect shipowners to pass on the benefit of the smaller levy by reducing freight charges. While the incidence of the levy varies, it is estimated that the saving to shipowners on general cargoes between Sydney and Melbourne should be two shillings per ton.

War-time Operation of the Smaller Ports.

The House of Lords on March 4th approved the Civil Defence (Transport) Regulations under which canals, navigations, docks, harbours, and railways would be enabled to function in time of war. The regulations were introduced by Lord Hawke who stated that the rate of grant for canals and inland navigations would be 52¾ per cent., for docks and harbours, 70 per cent. and 100 per cent., and for railways 100 per cent. In the docks provision would be made for the protection and duplication of vital machinery, for spare lock gates, moorings etc.

The ensuing debate was mainly concerned with the amount of the grant for small ports, Lord Saltoun stating that the Dock and Harbour Authorities' Association were concerned with the difficulties with which some such ports would be confronted if they were called upon to provide even only 30 per cent. of the cost. He instanced small communities of fishermen running their own harbour accommodation and said that it might be an onerous charge on a small and struggling port. The association were also concerned about the penalties which could be imposed. Many small ports had their debts guaranteed by outside parties and it was not fair to put these guarantors in the position of having to secure losses which might be caused by the imposition of these heavy penalties. Viscount Alexander of Hillsborough drew attention to the amazing accomplishments of the little ports with a population of only 1,000 or 2,000, during the war. Where the 70 per cent. grant was inadequate he thought that it should be raised to 100 per cent.

To these criticisms Lord Hawke replied that the 70 per cent. for " due functioning measures " was fixed by negotiation with representatives of docks and harbours. He agreed that there might be hard cases among the small harbours but there was also little likelihood of small penurious harbour undertakings being asked to undertake " due functioning measures." If additional facilities had to be provided they would get the 100 per cent. grant. The Dock and Harbour Authorities' Association had been assured that in cases of extreme need loans might be made by the Exchequer to help them to meet their share of the expenditure. The regulations were approved.

The Port of Dakar

The Reconstruction and Enlargement of Mole No. 1

By M. GIRAUD, Engineer-in-Chief.

A general descriptive article on the Port of Dakar appeared in the February 1952 issue of this Journal. The projected reconstruction and enlargement of the important Mole 1 was only briefly mentioned however, and the present article deals in particular with the technical features of the new mole. The greater part of this has now been put into service and is complete except for the installation of quay-side cranes, which are still on order.

Mole I of the Port of Dakar, which was recently put into use, is one of the structures that arouse most interest among visitors to the port, as it immediately catches the eye with its two-storey sheds and because it is a great success both in a general way and (as far as can be judged from first results) from the point of view of day-to-day operation.

The new mole was designed to cope with general cargo trade to the amount of a million metric tons a year, consisting mainly of imports. It replaced an old mole which provided too shallow a depth of water and which could no longer meet the requirements of modern trade.

The new mole was planned with a view to dealing rapidly with the discharge of goods from vessels. It was, in particular, designed so as to enable the vessels to berth alongside in uninterrupted succession without at any time being hindered by the presence of loads of cargo dumped on the mole by previous vessels.

Location and Orientation of the Mole

The mole is located in the South Zone of the port, which is the zone traditionally used for general cargo, being situated close to the commercial district and the centre of the town, whereas the North Zone of the port is used more for special commodities: ground nuts, coal, phosphates, petroleum products, oil, wine, etc.

Dimensions of the Mole

The mole is 450 m. in length by 150 m. in width and provides 10 m. minimum depth of water at lowest water levels. Three vessels can berth alongside each lateral face of the mole, plus one at the end face. (At present, the two south-west berths of the mole are not in use for accommodating large cargo vessels, as the necessary dredging operations have not yet been carried out.)

Storage and Transport Facilities

Each berth is served by a two-storey transit shed which provides 1,000 sq. metres of covered storage space at ground floor level and 1,500 sq. metres on the first floor. Large open spaces are provided between the sheds, so that the sheds present no serious obstruction to traffic on the mole; at the same time, however, these open spaces are in great demand as storage areas, as Dakar has a dry season lasting more than seven months of the year; the rainy season, on the other hand, coincides with the slack period in the general cargo trade.

The mole is served by two railway tracks on each side and by three central tracks.

In addition, pipelines for water and oil run the full length of the mole. These pipelines are located in ducts covered by pre-stressed concrete slabs, which, in the event of accidents, enable damage to be readily located and quickly repaired.

Lorries serve the upper storeys of the sheds at front and back. The upper storeys of all the sheds are interconnected and are reached by an access ramp at the root end of the mole.

Cargo-handling Equipment

In providing the equipment for Mole I, the nature of the goods handled and, at the same time, the traditional working methods employed at Dakar had to be taken into consideration.

At present, vessels landing goods at Dakar do not as yet use quay cranes and discharge their cargoes entirely by means of their own derricks.

Cargo-handling and lighterage do not enjoy any sort of monopoly, and these services are performed by various companies which are often at the same time shipping companies or affiliated to such companies. The sheds are mostly rented by these cargo-handling companies and by the companies operating regular steamship lines, but fairly numerous requests for renting shed space are received from forwarding agents or large import firms which act as their own transport agents.

The goods unloaded by the ships' gear is in most cases handled by fork-lift trucks or mobile cranes and placed in the sheds or taken to the storage areas. These operations are performed as expeditiously as possible, the goods first being roughly sorted; this is followed by more detailed sorting and the goods are then taken away by the consignees or, as is frequently the case, by their forwarding agents after a sojourn on the mole varying from 5 to 15 days.

The goods are for the most part transported by road.

The scheme of equipment takes this method of operation into consideration and, in particular, provides for the free movement of mobile handling plant between the zone where the goods are placed by the ships' derricks, the inside of the sheds and the open storage area. This requirement necessitated the provision of ample clearance under the overhead supporting beams (6.50 m. headroom on ground floor and 5 m. on the first floor).

The headroom of the upper storey is limited to the lower figure in order to prevent goods from being stacked up too high, as the floor is designed only for a load of 3 tons per sq. metre; this precaution was adopted in spite of the restrictions it imposes on the use of certain types of cargo-handling equipment requiring greater headroom.

Quay Cranes

The type of crane to be installed is so designed as to give the maximum amount of service, viz.: it must, on the one hand, be powerful enough to lift practically any load that may occur, and on the other hand, each of the cranes must be capable of serving an area large enough to allow very considerable amounts of cargo to be landed and roughly sorted out without involving too many handling operations by the equipment for horizontal transport.

In view of the above requirements, the cranes ordered are of the electrically operated semi-portal type, their lifting and slewing speeds being in accordance with the standard requirements laid down by the Ministry of Public Works, with a height of 22 m. under the hook and a radius of 27 m. The slewing axis is set back some distance, and this arrangement, in conjunction with the radius of the crane, allows points up to 35 m. from the water's edge to be directly served.

Railway Tracks

The railway tracks with which the mole is equipped are connected to the Dakar/Niger network of the French West African Railways and are operated by this network. They are metre-gauge tracks consisting of grooved rails of the type Broca SEI 56 placed on longitudinal concrete beams and embedded in the road surface.

The mole is served by two tracks along the edge of each quay and three tracks down its axis.

Goods Lifts

The cranes can pick up loads up to 6 tons in weight from the ship and place them on, or lift them off, any of the balconies or flat roofs.

The first floor of the sheds is moreover provided with road access, so that it can be directly reached by lorries.

It was nevertheless considered advantageous to improve upon

The Port of Dakar—continued

this system by supplementing it with goods lifts of 6 tons lifting capacity.

All loads which are not of too fragile or too bulky a character are lowered by means of chutes, which will be discussed below; but lifts had to be provided for dealing with fragile or bulky loads and, in particular, for motor cars, several thousand of which are received in Dakar each year.

These vehicles are unloaded on to the upper storey roofs of the sheds, which are particularly suited for the purpose.

Chutes.

The greater part of the non-fragile goods, especially goods in bags, are lowered to ground level by means of spiral chutes, designed so as to regulate the speed of descent, which convey the goods to the loading platform at the axis of the mole.

In order to reduce to a minimum the labour involved in loading the lorries and wagons, the chute terminates in a receiving table which is capable of being raised and which is set at a convenient height for receiving the goods. This table reaches to within 1.50 m. of the lorries or wagons to be loaded.

Five such chutes are provided per shed.

Water Supply Pipelines.

Dakar is almost the only West African port where water is supplied *ad libitum*: this is one of the great advantages enjoyed by ships using Dakar as a regular port of call, but it is of great importance for vessels which trade to the West Coast of Africa, for these vessels go for weeks without touching at any port where they can obtain water on anything like acceptable terms.

Mole I is equipped with encircling pipelines of 250 mm. diameter and 21 quay-side hydrants of 100 mm. diameter, each capable of supplying 100 cubic metres of water per hour.

In order to facilitate the execution of any repairs that may be necessary and the detection of leaks, and in order to have the maximum safeguard against pollution of drinking water in the event of joints becoming faulty, the pipes are laid in a duct situated above high-water level and accessible for inspection along its entire length.

Fuel Oil Pipelines

The main installations for supplying fuel oil to vessels are located in the North Zone of the port and are grouped around the petroleum basin. But, at the instance of the oil companies, the quays of the South Zone of the port have been equipped with fuel pipelines, so that vessels coming to these quays for carrying out considerable loading and unloading operations may take in their fuel supplies without having to call in the services of tank lighters or move to a different berth.

Unloading heavy machinery by ship's derricks.

General view of Mole I.

In view of these circumstances it was decided to equip Mole I with a communal supply pipeline.

This pipeline, which is entirely accommodated in ducts which are accessible for inspection, is 300 mm. in diameter, with three quay-side supply points of 200 mm. diameter, each of which is capable of discharging 100 tons of oil per hour.

All the pipelines installed in the port are of steel. In this particular case, cast iron pipes were employed, a high proportion of which were of malleable cast iron.

Lighting and Electrical Equipment

Experience has shown that it is advantageous to ensure very good lighting on the quays. This advantage is of a dual character: in the first place, the safety of the goods and men can only be safeguarded at night if very good lighting is provided; secondly, if the illumination of the quays is excellent, the shipowners will not object to letting work go on during the hours of darkness.

A particularly powerful system of lighting has accordingly been installed, using yellow sodium light and comprising 300 floodlights of 10 watts each.

In addition, the electrical equipment includes the supply of power to the cranes, goods lifts, and power supply points for any other machinery that the cargo-handlers may wish to employ.

Method of Construction

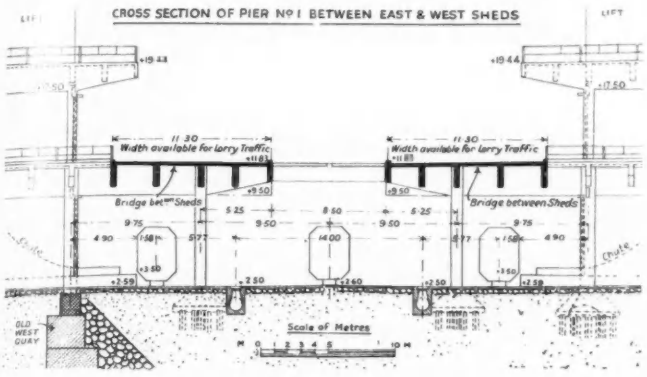
Quay Walls.

The subsoil in the region of Mole I consists of heterogeneous conglomerates, of which the hardest components are lumps of basalt (some of which are several cubic metres in size), while the worst component is a compact form of clay with a cohesion of 400 grammes/cm² and an angle of internal friction of 19°. This clay is not present in large masses, but acts merely as a connecting matrix for the rocky components.

Having regard to these data and to former experience at Dakar, where quay walls composed of blocks have been built for fifty years without any displacement ever having occurred in the South Zone of the port, the system adopted for the construction of the quay walls consisted in following old-established methods, viz. dredging a trench of 80 cm. to a level of −10.80, this trench afterwards being filled with rubble which was laid to a level surface by divers.

The actual quay wall was constructed upon this rock fill and is composed of hollow blocks weighing 50-100 tons and made of concrete with a cement content of 350 kilogrammes per cubic metre.

The Port of Dakar—continued


CROSS SECTION OF PIER Nº I BETWEEN EAST & WEST SHEDS
Width available for lorry Traffic
Bridge between Sheds
Scale of Metres

no means certain that it could be dealt with by conventional methods. Tests with explosives were not very successful, on account of the presence of large cracks, and it was finally decided to break up the mass of rock gradually by pounding it to pieces. It is now practically certain that the desired final depth of 10 m. will be attainable by this method.

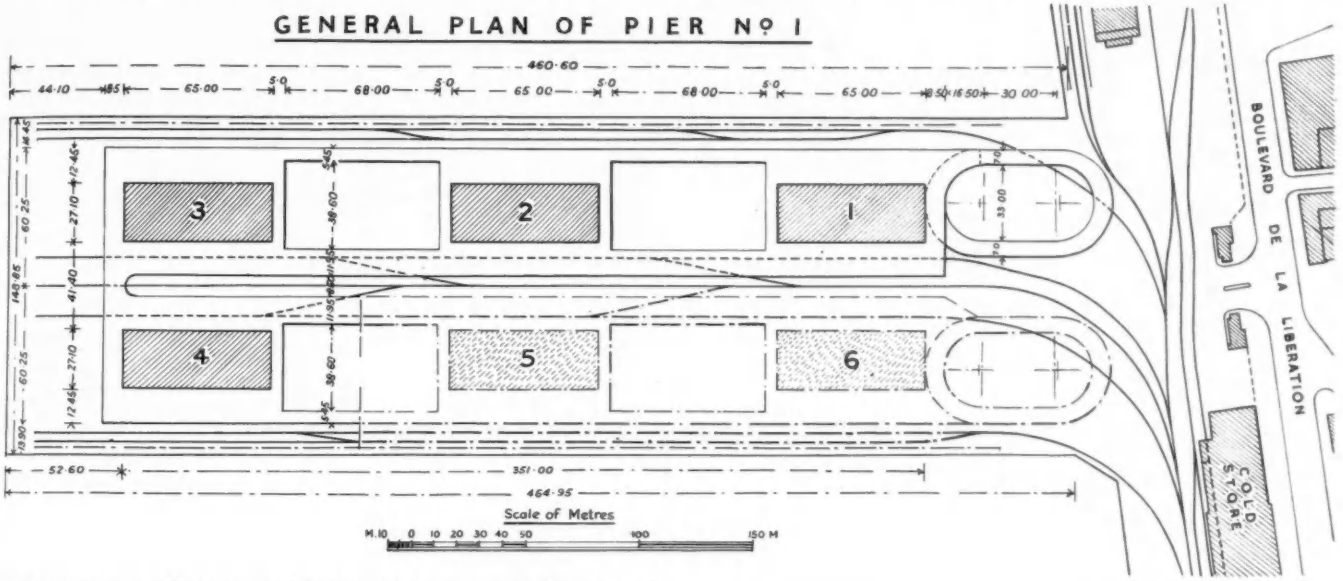
The fill material was dumped mostly by hydraulic methods, using coarse sand dredged from the sea bed, conveyed in barges and deposited within the body of the mole.

In driving the foundation piles for the sheds, this " hydraulic " fill of shelly sand was found to be absolutely imcompressible; its bearing capacity was far superior to that of the underlying soil consisting of more or less compact marls.

Surfacing and Drainage

A bituminous road surfacing with a 30 cm. thick stone foundation was employed. This type of surfacing is rather costly to maintain, especially when it becomes damaged by exceptional loads dumped on it (heavy tractors, wagons, bulky structural units), but it is easy to repair. Besides, it is hoped to considerably reduce wear and tear by applying a 4 cm. thick top bituminous wearing coat.

Rain water is drained away mainly through a system of pipes which are accessible for inspection.

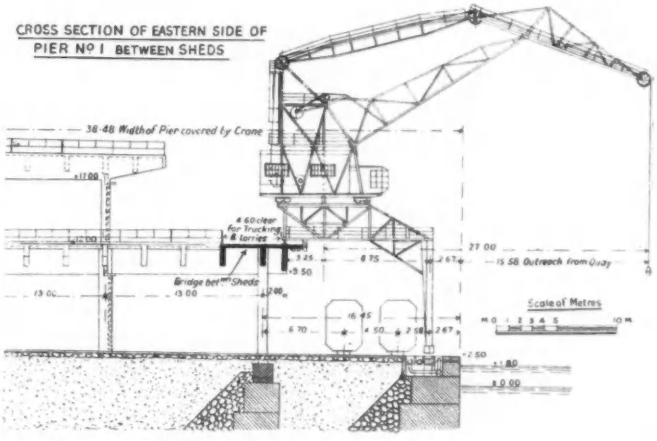


The only new feature consisted in using some specially shaped seating blocks with a view to equalising the bearing pressure on the foundation or to effecting some saving in the volume of concrete employed. In order to equalise the settlement, the blocks are laid in bonded courses, i.e., continuous vertical joints are avoided. This method of laying the blocks is sometimes objected to on the ground that cracks may occur in them ; but it was adopted in this instance without misgivings, because in the case of similar work carried out at the port no cracking of the blocks was ever encountered.

The superstructure was poured in situ from +1.00 m. to +2.50 m. level.

Behind the block wall was placed a conventional rubble backing of prismatic section, and, in order to prevent the escape of fill material through the voids between the lumps of rock, the rubble backing was separated from the main body of fill material forming the mole by an impervious seal consisting of quarry waste composed of a mixture of stones and clay in naturally formed proportions which are found to be excellent for the purpose.

Dredging was carried out by two steam dredgers with buckets of 400 litres capacity, whose output was about 500 cubic metres per day for average dredging conditions. Where the bottom was rocky, the rock first had to be broken up by pounding. Dredging presented a difficult problem owing to the presence of a mass of basalt, the extent of which was not properly known, in the western basin of the port. Borings showed this mass of basalt to be confined to a rectangular area about 30 m. in length and 8 m. in width and reaching a level of −4.40 m. For a long time some hesitation had been felt with regard to fixing the dredging depth in the eastern basin, as borings had shown that this basalt formation extended downward beyond the level −12.00 m. and it was considered by


CROSS SECTION OF EASTERN SIDE OF PIER Nº I BETWEEN SHEDS
38·48 Width of Pier covered by Crane
Bridge between Sheds
Scale of Metres

Layout of the Sheds

Competitive designs having been received, a solution comprising monolithically constructed reinforced concrete sheds provided with an upper storey was chosen.

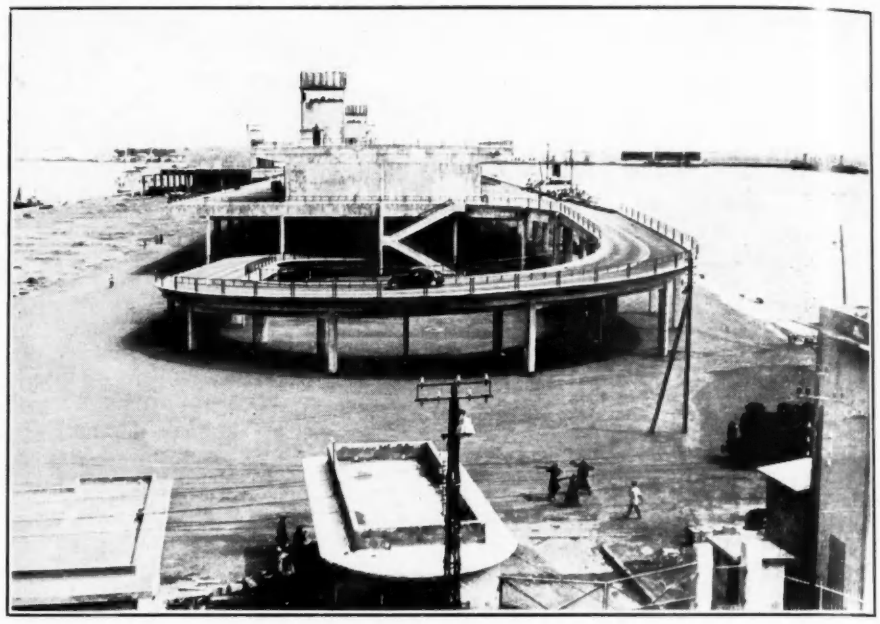
The Port of Dakar— continued

The columns are spaced 13 m. apart in both directions, this distance being considered adequate for allowing lorries to manœuvre, while it was difficult to increase the column spacing above this figure without excessively increasing the weight of the structure, having regard to the superimposed load of 3 tons per sq. metre for which it had to be designed. Even so, the loads on each column are very high, being 1,000 tons on each of the main columns.

The sheds are founded on reinforced concrete piles of 75 tons bearing capacity, connected at the top by large load distributing caps.

The elevated roadways connecting the transit sheds with one another, under which the traffic serving the open-air storage areas (and involving the transportation of particularly bulky loads) has to pass, are placed on lines of columns spaced 19 m. apart, thereby ensuring considerable ease in the manœvring of lorries.

As a measure of economy, and considering that it is not likely to be used very intensively by lorry traffic, the flat roof of the second storey was designed for a superimposed load of only 1,500 kilogrammes per sq. metre.



Access ramp to upper storey of transit sheds.

The sheds are of conventional reinforced concrete construction and call for no special remark, except in so far as certain special precautions are concerned: the purpose of these precautions is to safeguard the concrete against the harmful effects of sea-water and salt spray and to resist the horizontal forces exerted by the cranes.

As a general measure, and for reasons of economy, all the buildings are reinforced with semi-hard steel bars with a working stress of 18 kg./mm.^{2} But in order to avoid the special danger arising from the formation of cracks in reinforced concrete exposed to attack by salt water, the piles—which are driven into ground that is saturated with sea water and a certain part of which is moreover situated between high and low tide—are reinforced with mild steel with a permissible working stress of 13 kg./mm.^{2} The external beam, on which the crane track runs and which is exposed to the action of spray, is provided with a semi-hard steel reinforcement, but in this case the permissible working stress has been limited to 16 instead of 18 kg./mm.^{2}

No special precautions were taken with regard to the outer columns of the sheds, as these columns are normally under full compression, and the danger of cracking is not so serious as in the tensile zone of beams subject to bending.

The access ramps have a gradient of only 5.5 per cent., with curves of 30 m. radius; they are 7 m. wide on the straight portions, with a considerable widening at the curves.

Expansion joints, 2 cm. in width and spaced at distances of about 75 m., have been provided in the sheds and access ramps. Continuity and water tightness at these joints is ensured by the insertion of a water stop made of copper strip and a mastic asphalt filler.

The sheds were constructed by the Société Dumez.

The doors, which are 5 m. in height, are of the rolling type and extend along the entire length of the quayside face of the building.

Roof Coverings of the Sheds

The system employed, viz. sheds with load-bearing flat roofs capable of being used for depositing goods, forced us to construct these to comparatively small falls for the run-off of rain water. A fall of 2 per cent. was employed on all parts not roofed over.

With such small falls, the covering must be properly impervious and it must at the same time be able to stand up to the effects of road traffic and cargo-handling operations. When, in the end, damage inevitably occurs, it must be possible to carry out repairs of a local nature.

In order to satisfy these requirements, a mastic asphalt covering, with ten years' guaranteed water tightness, was employed. This covering has a thickness of 1.5 cm. in places exposed to heavy traffic loads; if the material were applied in greater thickness in such places, it would run the risk of being squeezed away. Besides, the traffic loads tend to close up any cracks that may occur, so that chosen thickness is adequate under such conditions. On the roof of the second storey the mastic asphalt covering has been made 2.5 cm. thick, as this part of the structure is not subject to such intensive use.

Mobile crane loading timber on to railway wagons.

Improvements at the Port of Valparaiso.

Major improvements, estimated to cost 600 million pesos, are planned for the port of Valparaiso. It is expected that the greater part of the work will commence in 1955 and will take 5 years to complete. It is proposed to extend the mole by at least 500 metres which would more than double the extent of the sheltered anchorage. A new warehouse costing 18 million pesos will be begun this year and improved mechanisation of the cargo-handling facilities is to be carried out during the next three years at a cost of a further 70 million pesos.

Dock & Harbour Authorities' Association

Excerpts from Report of Executive Committee

At the annual general meeting of the Dock and Harbour Authorities' Association, held in London on 24th February last, the report of the Executive Committee, for the year ended 31st December 1953, was approved and adopted.

After outlining the action taken during the year in connection with legislation in Parliament affecting U.K. ports, the report refers to the Transport Act 1953, and comments as follows on matters which arose during the year under that Act.

(i) **Reorganisation of the Railways:** In April, the chairman of the British Transport Commission visited Scotland to meet representatives of bodies interested in the proposed reorganisation of the railways and to learn their views before the preparation by the commission of the scheme for Scotland.

Lord Hurcomb expressed a desire to meet representatives of dock and harbour authorities in Scotland, and a meeting was accordingly held at the offices of the Clyde Navigation Trust, at which representatives of the principle ports in Scotland were present. Lord Hurcomb explained that the commission had in mind to set up a local board which would be responsible for the whole of Scotland. The board would be a small one consisting of not more than seven members, two of whom would be members of the commission.

It was likely that the chief official of the Scottish board would conduct the day-to-day business of the board, being responsible for it to the board, but, as required by the Transport Act, 1953, the general financial control and the general control of charges would remain in the commission. It was envisaged, however, that the board would be given financial powers within certain limits and power to recommend schemes to the commission and to formulate proposals.

Lord Hurcomb confirmed that there was no intention to put the Scottish ports owned by the commission under the railway region, and he expressed the view that there would be no change in the existing relationship between the independent port and the railways.

The representatives of the Scottish ports indicated to Lord Hurcomb that, generally speaking, they welcomed the proposals and were particularly glad that no change was proposed in the existing relationship between the independent ports and the railways.

(ii) **Commission's Ports and Dock Undertakings:** As stated in the association's annual report for 1952, at the committee stage of the Bill, in dealing with an amendment set down by the association, the Minister of Transport stated his view that it would be extremely difficult to break up the gross operating costs of several activities and the net results of each activity after charging the due and proper proportion of central charges. He added that the commission thought that this task would be almost impossible.

This question was considered by the accountants' sub-committee of the association, who prepared a memorandum in which they expressed the view that it would be feasible to break up the central charges of the commission and suggested alternative methods how this might be done.

The association believe that the commission should be required to break up the central charges in their accounts and to allocate the proper proportion to each undertaking and separate accounting unit, so that the true financial position is shown in the accounts. They will continue to press for the necessary direction to be given to the commission.

Explosives Storage

During the year, discussions continued with the Explosives Storage and Transport Committee and the Treasury Solicitor, on the subject and form of the new "Conveyance of Government Explosives in Harbours Regulations." These regulations were eventually made at the end of November and came into force on December 10th.

In consequence, Regulation 76 of the Defence (General) Regulations and the Government Explosives in Harbours Order, 1939, which were made under Regulation 76, were allowed to lapse on December 10th.

The association considered two re-drafts of the new regulations and raised a number of points which, with one exception, were dealt with in the regulations as finally made.

This exception, the report adds, is a matter to which the association attach considerable importance and relates to the precautions to be taken for the safety of the harbour. Under the provisions of Regulation 4, these precautions are to be determined by the harbour master, after consulting the Government representative, but the regulations do not specify who is to be responsible for seeing that they are taken. The association suggested that the Government representative should be made responsible and that a new paragraph providing for this should be added to regulation 19.

The explosives storage and transport committee, in rejecting this suggestion, stated that the Government representative may be a non-commissioned officer, warrant officer, or a young officer who may have little experience of the practical side of the work of the docks and would not have the prestige and power comparable to that of a harbour master in his own area.

The association have, however, pointed out that under the Government Explosives in Harbours Order, 1939, which has now lapsed, a duty was laid upon the representative of the Government department to consult the harbour master and to take all due precautions for the safety of the harbour area. The association consider that it is undesirable to change this practice.

As indicated in the interim report of the Ministry of Transport's Working Party in 1949, dock and harbour authorities have from the outset expressed their apprehension at being asked to handle Government explosives in docks during peace-time. As, however, it is necessary to do so in the national interest, they have been willing to co-operate and have co-operated, but they have always made it clear that the regulations must be framed in such a way that, so far as is possible, the port authority are properly safeguarded and that authorities are adequately indemnified against the consequences of an explosion.

The association are anxious that all precautions should be taken so as to prevent, so far as that is humanly possible, an explosion, the results of which might be incalculable. They feel that an elementary safeguard is to lay down in the regulations the responsibility for seeing that precautions determined to be necessary are taken.

The association believe it to be of the greatest importance that the regulations should be amended to cover the point they have raised and the matter has accordingly been raised again with the Minister of Supply and the heads of the Service Departments.

Oil Pollution

After the publication last July of the report by the committee set up by the Ministry of Transport to consider what practical measures should be taken to combat oil pollution, the association were asked their views.

In stating them, the association welcomed the recommendations of the committee for the prohibition of the discharge of persistent oils into the sea, either altogether or, as immediate policy, within certain zones, and made the following points:

(a) **Deep-sea Tankers and Coastal Tankers.** The association supported the recommendation of the committee as to the provision of reception facilities at loading and repair ports in the United Kingdom by oil companies and ship repairers respectively, and accepted the recommendations that dock and harbour authorities should have power to co-ordinate the provision of comprehensive facilities.

(b) **Dry-cargo Ships.** The association concurred in the recommendations made by the committee respecting the provision of facilities for the reception of oily residues from dry-cargo ships, and indicated that they would be prepared to co-operate in providing or securing the provision of adequate reception facilities.

The association had previously stated their view to the committee, that the facilities to be provided for dry-cargo ships would necessarily vary from port to port, and that it would be difficult to include in the general legislation requirements relating to the provision of such facilities, which would be of general application.

They suggested instead that the Minister of Transport and Civil

Dock and Harbour Authorities' Association—continued

Aviation should be empowered to require or secure the provision of the necessary facilities if, after a lapse of a reasonable time, he is satisfied that adequate reception facilities have not been provided at a particular port.

The committee included this as a recommendation, and the association informed the Minister that they agreed in principle with this recommendation, though they reserved the right to make representations on the wording of the statutory provision, if and when it is introduced.

The association also made the point that the legislation should include power to dock and harbour authorities to make reasonable charges for any facilities provided by them.

(c) **Sources of pollution other than those in ships.** The Ministry were informed that the association were generally in agreement with the findings of the committee under this head and the association expresed the hope that the strengthening of the provisions of the Oil in Navigable Waters Act, 1922, and the new legislation would result in very little, if any, oil finding its way into docks and tidal waters under the jurisdiction of a dock or harbour authority.

They referred to the fact that, at the present time, the known methods of removing oil from docks are expensive and unsatisfactory and pointed out that the removal of such oil presented a difficult problem, particularly in tidal waters.

(d) **International Conference.** The question of oil pollution was considered at an International Conference on Oil Pollution of the Sea which was held in London in October, at which the chairman of the executive committee read a paper entitled " The Ports Point of View."

The Minister of Transport, in opening the International Conference, announced that the Government proposed to call together the principal maritime nations for the purpose of considering the best means of preventing oil pollution of the sea. It is understood that the meeting will be held in April, 1954, and it is hoped that some general agreement will be reached between the principal maritime nations so that some more active steps can be taken to deal with this problem.

The association have made it clear that they will do all in their power to help solve the problem and they have given an assurance to the Ministry that, where in the past it has been the practice periodically to deposit waste oil and oily mixtures into the sea outside territorial waters, arrangements will be made to discontinue the practice in advance of any general prohibition which may result from the committee's recommendation.

Contracts for Civil Engineering Works

During the year, a special sub-committee appointed by the executive committee considered the latest redraft of the General Conditions of Contract for use in connection with works of Civil Engineering Construction, which has been prepared by the Institution of Civil Engineers jointly with the Association of Consulting Engineers and the Federation of Civil Engineering Contractors.

The association take the view that some amendment is required to the Standard Conditions in their application to dock and harbour works, but the consideration of the matter has necessarily taken some time. It is, however, hoped that early in the New Year the association will be in a position to make their views known to the bodies responsible for drafting the Standard Conditions.

V.H.F. Radio Telephony

Early in the year, the association were informed that the possibility of a change from amplitude modulation to frequency modulation for V.H.F. equipment was being considered. The matter was, therefore, raised with the Overseas Telecommunications Department of the General Post Office, to whom the association pointed out the importance to port authorities of the proposed change. In a number of ports, considerable sums have been spent in installing V.H.F. equipment using amplitude modulation and, following the lead given by port authorities, V.H.F. equipment has been installed in a considerable number of vessels, so as to enable them to communicate with the port authority.

The Overseas Telecommunications Department confirmed that the matter was being reconsidered, both nationally and internationally, with a view to securing world-wide agreement to the use of one system of modulation on frequencies which have been or, it was hoped, would be assigned internationally for specific purposes.

Subsequently the association discussed this matter with representatives of the Chamber of Shipping, the Liverpool Steam Ship Owners' Association and the Tug Owners' Association. Following these discussions the Overseas Telecommunications Department were informed that, if world-wide standardisation, which was clearly desirable, could only be achieved by changing from amplitude to frequency modulation, the association would agree to the reopening of discussions on this basis.

The association have suggested, however, that, if a change is to take place, there should be safeguards which they would be prepared to discuss at a later stage. Generally speaking, the association propose that changes of equipment should not be called for in cases where the use of amplitude modulation would not affect international services and that, in other cases, a reasonable period should not be allowed before existing equipments have to be replaced or the use of frequency modulation made compulsory for new equipment.

Engineering Joint Committee

At their quarterly meetings the Joint Committee of the association, the Docks and Inland Waterways Executive and the Railway Executive discussed various matters of common interest, including the following:

- Fendering at River Entrances.
- Lock Entrance Machinery.
- Mooring Chains.
- Pneumatic Breakwaters.
- Spartina Townsendii.
- Equipment at Graving Docks.
  - (a) Provision of lifts.
  - (b) Installation of sewage disposal arrangements at dry docks.
- Practicability of Using Television Cameras for Underwater work.
- Use of Explosives in Dock Construction Works.
- Plant and Tools for Dock Maintenance and Construction Works:
  - (a) Mechanised track cleaning.
  - (b) Use of power compressors for air supply to divers.
  - (c) Air compressors mounted on tractors.
- Use of Galvanised Wire Ropes.
- Rail track lubricators.
- Entrance locks and dry docks — substitutes for granite in quoins and sills.

Prevention of Pollution of the Sea by Oil

Factories Acts, 1937 and 1948. Draft Regulations for works of engineering construction.

Association Studentship

In order to encourage the study of matters of interest to dock and harbour authorities, the association have decided to give an annual studentship. The studentship will be open to employees of dock, harbour and conservancy authorities in the United Kingdom and will be given to the candidate who, in the opinion of the Institute of Transport, submits the best paper each year on a subject relating to a dock, harbour or conservancy matter.

The association propose that the successful student should study such aspects of the administration or work of a port authority as he may choose at one or more ports in the United Kingdom. They propose that this study should last for not more than two months and they feel sure that members will co-operate in offering facilities for this purpose.

The association will make a grant of one hundred pounds to the successful student with the object of reimbursing him the amount of any expenses necessarily incurred in connection with the course of study. The method of payment of the grant will be decided when the studentship is awarded.

Harbour Surging at Cape Town, South Africa

General Conclusions of Recent Researches

By BASIL W. WILSON, D.Sc., C.E. (Illinois), A.M.I.C.E., Assoc.M. A.S.C.E., A.M.(S.A.)I.C.E.

THE phenomenon of Range-action or Surging (known also as Run, Scend, Groundswell, Seiche, Surf or "Ressac," in various harbours of the world) seems to have developed at Cape Town with the opening in 1869 of the Alfred Basin, now the innermost dock of the present Table Bay Harbour (Fig. 1). The history of the problem at Cape Town shows that surging was a prominent factor in influencing harbour development there, but until 1942 the phenomenon was not fully understood, chiefly because it remained so largely invisible and intangible in all but its effects. The seriousness of its action upon shipping in the critical years of World War II, when large east bound convoys were using the Cape route, finally precipitated the studies of which this paper may be said to be a summary.

The pattern followed by the researches was woven round accumulated information on actual troubles experienced and local understanding of them, which necessarily involved the oceanographic and meteorological conditions surrounding their occurrence. Bibliographical studies soon uncovered the fact that these sporadic sea disturbances were actually part of a world wide coastal phenomenon parallelly related to the earlier recognised phenomenon of seiches in lakes (1).

Scientific recordings of incidences of Range-action at Cape Town were made during the years 1943-46 and were correlated with concurrent weather conditions at the port and farther afield over the South Atlantic ocean. Attempts were made to analyse the influences of the possible disturbing agencies—seismic, meteorological or artificial.

A large engineering model of Table Bay and its harbour was constructed at Cape Town and in this the Range phenomenon was successfully reproduced and means investigated for abating its ill effects upon shipping.

Origins of Surging.

Surging has been found to develop from the incidence of long ground-swells on the western and southern coasts of South Africa, arriving from sources in the adjacent south-western ocean.

The phenomenon has been correlated with the passage of frontal depressions across the South Atlantic. The depressions travel in general on a south-easterly course at speeds of from 30 to 40 knots, passing, usually, far south of Cape Town (Fig. 2). Violent winds blow clockwise round the depression centres, their velocity increasing in proportion as the barometric gradient increases. Prominent cold fronts, or surfaces of discontinuity between conflicting warm and cold air masses, stretch in crescent formation over distances of 1,000 to 1,500 miles north of the depression centres. Along the line of the cold front cold air is continuously boring in under the warm air mass, as the whole formation progresses, bringing to Cape Town its winter squalls, sea-swells and Range-action.

Within the storm areas waves are whipped up by the winds, the most prominent periodicities of the waves being proportional to the wind speed. The wave trains of longest periodicity and greatest amplitude thus tend to originate near the storm centres and propagate with the greatest amount of energy.

It would appear that surface traction from high winds is capable of generating waves of periodicities up to a limit of about 25 seconds. Waves of periods of 15 seconds and more are probably assisted in their development by barometric fluctuations which increase with the wind speed and presumably take over the work of imparting energy to water in the form of still longer waves of periods exceeding 25-30 seconds (2).

Besides the wind-traction barometric-fluctuation source of sea-waves and ground-swells, theoretical considerations indicate that a train of wind-waves, passing clear of wind domination and free to propagate as a smooth procession, will of its own accord develop antecedent and sequent ground-swells through its natural tendency to attenuate.

A third source of ground-swells may lie in the sudden dissipation of a frontal low pressure cell. Ground-swells in this case could arise in certain circumstances from the gravitational flow under pressure of the released head of water near the depression centre.

Exceptionally long forced sea-waves can be generated by long period air-waves or barometric fluctuations, which appear to arise when one depression overtakes another (3).

Nature of Surging.

The sea-waves and ground-swells eventually roll into Table Bay. They may be brought in in the teeth of the wind with heavy rain

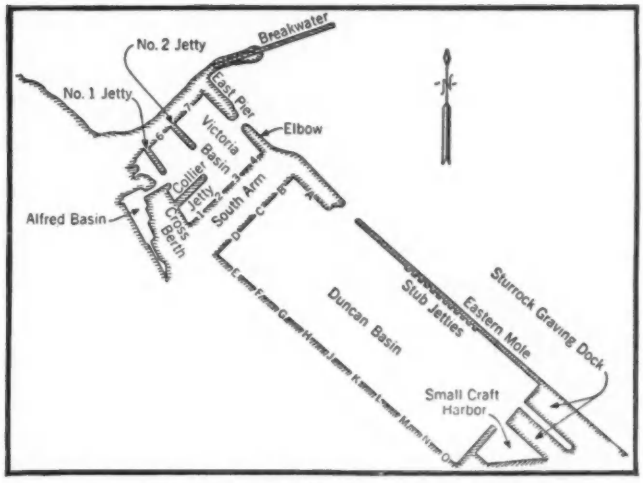


Fig. 1. Outline Plan of Table Bay Harbour, Cape Town.

when the cold front of a depression crosses over Cape Town, or they may arrive in clear, calm weather from remote distances in the South Atlantic.

The energy of the highest frequency waves (periods less than 15 seconds, say) is largely destroyed in the surf along the coast, but the longer ground-swells surge up the shore without breaking and reflect to form standing waves with oncoming members of their trains.

Where the topographical features of a bay, inlet or semi-enclosed basin favour it, the underlying ground-swells are repeatedly reflected and form resonant oscillations or seiches. The basin selects for this purpose only those of the incident waves as have about the same periodicity as its own natural periods of oscillation.

The special property of a seiche consists in a synchronous movement of the entire water mass of the bay or basin, in which every water particle moves in phase with every other. The seiches tend to be uninodal or multinodal by oscillating about one or more nodes where water particle movements are horizontal only (4).

Evidence has been adduced to suggest that even the South Atlantic Ocean itself performs slow molar perturbations under the influence (apparently) of the travelling depressions, the oscillations taking place between the mid-Atlantic ridge and the west coast of Southern Africa (5). Certain of the higher harmonic oscillations of this gigantic basin seem able to resonate in the bowl of Table Bay, and classify as forced seiches, impressing themselves upon the internal system of the bay.

Of its own accord Table Bay is able to respond to frequencies of disturbances which are too high to produce any effect upon the greater oceanic basin. The bay has been found to function very much like a composite of an ellipsoidal, circular and rectangular bowl, and has natural modes of oscillation peculiar to it. The most prominent periodicities, among many others, are 62, 51, 33-26, 23-17, 14-12, 11-10, 9.8-9.4 minutes.

In the same way that the forced seiches of the oceanic basin influence Table Bay, so the forced seiches of the bay are impressed upon the quasi-basin formed between the breakwater and the shore

Harbour Surging at Cape Town, South Africa—continued

(Fig. 2). As it chances, the 11-10 minutes seiche for the bay is exactly resonant for the breakwater-shore system, while the 14-12 and 9.8-9.4 minute forced seiches are near-resonant.

Quite apart from this, the breakwater-shore quasi-basin begets its own natural seiches of higher frequencies to which the bay is largely insensitive, and these in turn become the forced seiches to influence the harbour basins.

The troubles of Range-action peculiar to Table Bay harbour arise from the excitation of seiches within the docks which are sympathetic to the forcing seiches in the external roadstead. By an odd mischance the dimensions of the Duncan Basin and the location of its entrance favour the development of longitudinal and and 11 minutes in the Duncan Basin constitute oscillations about nodes within the basins, and these are the ones which are ordinarily referred to as Range. We may thus recognise two kinds of action that can take place, either singly or together, depending on the forcing seiches in existence. An oscillation may develop inside a basin and be sustained with relatively feeble transference of water through the basin mouth, or a comparatively slow rise and fall of water over the entire dock area may take place, accompanied by a powerful flux of water through the basin entrance. The first kind of action is dangerous to moored ships, while the second is for the most part dangerous only to ships being navigated through the dock entrances.

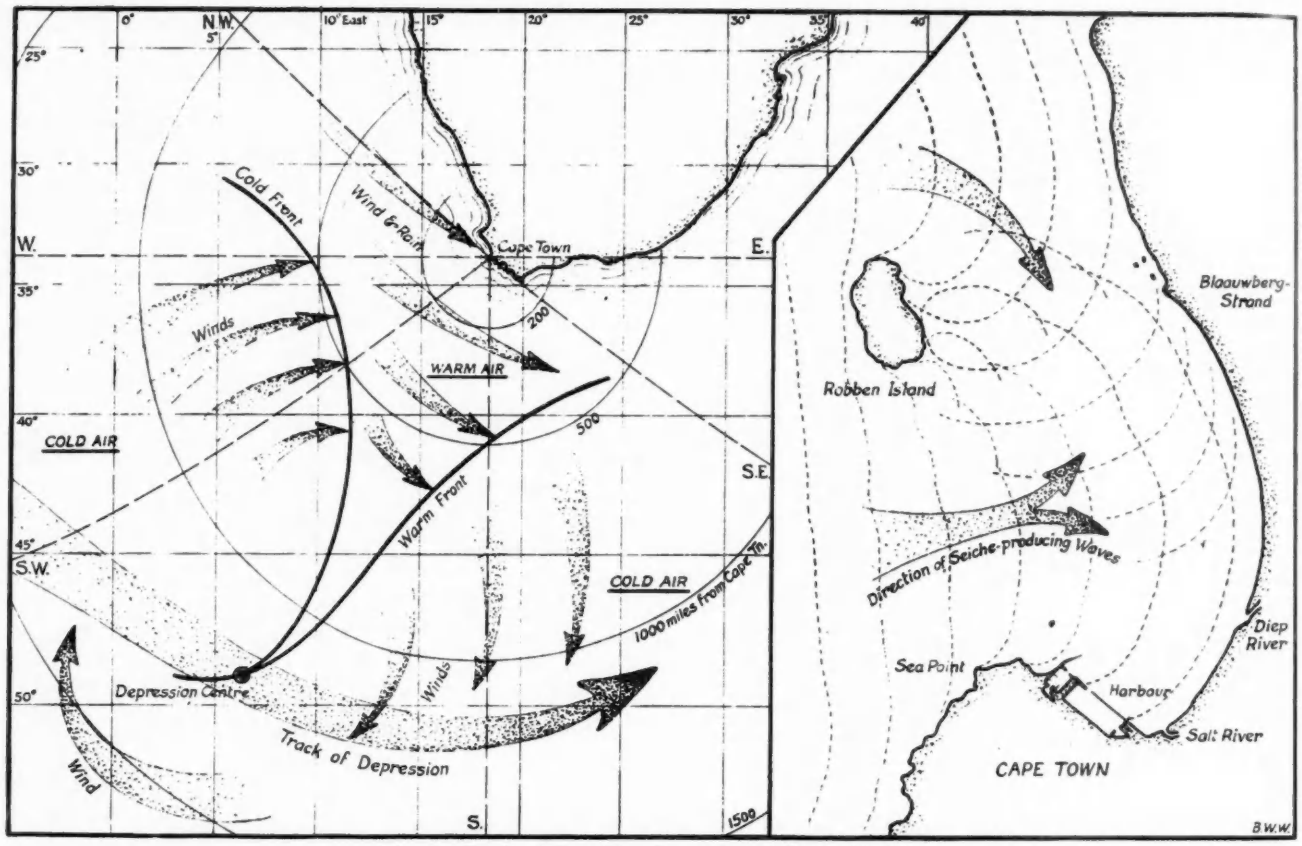


Fig. 2. Track of Travelling Depression of South Atlantic.

transverse seiches of the same periodicities as some of the harmonics of the breakwater-shore oscillating system. Not unnaturally the oscillations within the harbour basins are able to attain appreciable magnitudes.

For the Duncan Basin, which is almost exactly rectangular, the natural periods of longitudinal and transverse oscillation, in the fundamental (uninodal) modes, are respectively of the order of 5.6 and 1.8 minutes. For the Victoria Basin which is roughly square the fundamental oscillation is about 1.9 minutes. If we double the longest periodicity for each basin, we obtain a mode of oscillation in which the node is at the mouth of the basin and the antinode at the far end of the dock, most remote from the entrance. For the Duncan and Victoria Basins this condition obtains at periodicities of about 11 and 4 minutes respectively.

All forced seiches of periods greater than these respective latter figures act on the basins as surges through the entrances, which create a general rise and fall of water over the entire dock areas. Thus the 33-26 and 23-17 minute seiches of the bay impress themselves upon the harbour basins in this way, while many of the seiches of the breakwater shore system which have periods greater than four minutes impose themselves in like manner upon the Victoria Dock.

All seiches of periods less than four minutes in the Victoria Basin

Ship Response to Surging.

Internal oscillations in a basin affect ships by causing them to move longitudinally, laterally and vertically, sometimes with a roll, wherever a ship may happen to lie in the periodic (reversible) currents of the oscillation (6). Ships resist these movements by pulling on their mooring ropes or making contact with the floating fenders, but as the forces to be countered comprise the inertia of the ship and the pressure of the surge (which, in effect, doubles the inertia of the ship), it is easy to see how damage can result when large ships are involved.

In longitudinal motion along a quay a ship can resonate with the activating seiche provided its moorings are of the right order of slackness. It has been found from theoretical principles, verified by experiment and confirmed by actual measurements on ships (7) that the most dangerous conditions for ships as ordinarily moored prevail when seiches with periods of the order of two minutes and less attain large amplitudes in the harbour basins. It is known that second and third harmonics, respectively of periods 0.8-1.1 and 0.5-0.7 minutes, of the fundamental transverse seiche (1.5-2.1 minutes) in the Duncan Basin, can attain considerable prominence during severe Range-action. To the action of these high frequency seiches must therefore be attributed much of the troubles that have arisen from ships breaking adrift.

Harbour Surging at Cape Town, South Africa—continued

It has been shown that the size of a ship is not of the importance in longitudinal ranging that might be expected. Far more important are the magnitude of the seiches and the condition of the moorings. Large ships, however, tend to resonate at somewhat longer periodicities than smaller ships, but even for the largest ships it is still the multinodal seiches that are most critical. This, of course, is not to say that the effects of the prominent transverse seiches (1.5-2.1 minutes) are negligible: these, undoubtedly, contribute to the total effect of causing a ship, ultimately, to overstrain its ropes.

In lateral motion off and on a quay, a ship is, strictly speaking, unable to resonate, because the latitude for movement is far greater than the extent of surge and the essential spring-system is lacking. Nevertheless, if a ship happens to be off a quay by the right amount when an on-surge takes place, the forces of impact at the end of the movement, when acceleration is a maximum, can be very great. The mass of the ship is of the greatest importance in this case, for the force of impact (in part) is proportional to the square of the displacement tonnage.

As the greatest accelerations in the off-and-on movement are caused by the prominent multinodal seiches, the inference can be drawn that it is periodicities of about one minue down to say 20 seconds that are most critical for ships in this action.

A factor of considerable importance governing the behaviour of a ship during Range-action, depends upon the location within the harbour where it happens to be berthed. Some berths are worse than others according to the disposition of the nodes and antinodes of the various seiches: as the latter are largely invariable, it is possible to define the relative susceptibilities of different quays.

The worst berths in Table Bay Harbour are along the Eastern Mole (Fig. 1) where off-and-on action is very strong, but the stub jetties are partly to blame for this, owing to their effect in holding ships off the real boundary wall of the Eastern Mole, in consequence of which ships are subject to larger lateral displacements and accelerations than would otherwise be possible were they tied along a straight quay wall.

Of the remaining berths, B in the Duncan Basin is worst, with a 1 in 3 chance that ropes will be fractured there during an occurrence of Range-action. Several other berths in the Duncan Basin are also bad, as also are two or three in the Victoria Dock. Generally, however, the Duncan Basin shows a greater propensity for Range troubles than the older dock, and this can be ascribed very largely to its greater size and the smalier degree of protection it receives from the breakwater as well as to its unfortunate dimensions in relation to the external dimensions of the harbour, and the position of the latter in relation to the bay.

Over the years 1942 to 1949 there was a notable lessening of the magnitude and frequency of the Range disturbances at Cape Town, which now seems to be yielding again to a recurrence of severe troubles. It is likely that this trend is related to secular changes in the weather operating upon the travelling depressions of the South Atlantic. In the worst years of Range-action (1939-1942) there were about 40 occasions per year when Range-action was severe enough to cause rope breakages and other damage By 1945-46 this frequency had dropped to about 15 occasions per year and by 1948 it had probably decreased further, although this was not specifically checked.

The second type of action, which was noted as affecting only the navigation of ships through the basin entrances, does not ordinarily reach troublesome proportions concurrently with the first type of action (involving ship ranging), except in the Victoria and Alfred Basins. In these two basins surging at the mouths can be very unpleasant during severe Range-action, as a result of forced seiches with periods from 4 to 12 minutes, but it requires seiches of longer periodicities than this to create the equivalent effect at the mouth of the Duncan Basin, and the forced seiches of the bay, which do it, are not usually at their worst when strong Range-action of the first type prevails.

The long-period seiches of the bay have been found to reach large amplitudes under the influence of prominent air-waves or barometric fluctuations, simultaneously with their crossing over Cape Town. The effect of these seiches upon the Duncan Basin is to cause a violent flux and reflux of water through the entrance at velocities up to four or five knots, often persisting intermittently for as long as two or three days. The phenomenon has been found to occur as often as 10 to 15 times a year, and to reach really dangerous proportions on perhaps two or three occasions per year.

While collisions of ships with fixed structures have been narrowly averted at the Duncan Basin entrance, they have on rare occasions occurred in the more confined spaces of the Victoria and Alfred Basins. As the spate of the reversible currents can influence the navigation of a ship, it is always potentially dangerous.

The Solution of the Surge Problem.

The ideal solution to the surge problem would be one which reduced the internal oscillations in the harbour basins to harmless proportions and eliminated dangerous currents from the entrances, leaving the port free and untrammelled for the normal conduct of its business. The solution, moreover, must cure the surging troubles without raising any fresh problem, engendered by its application.

Such an ideal solution, however, is unattainable for the reason that there is no known method of combating the currents in the basin entrances, short of sealing them off entirely. The best that can be done about these surges is to ensure that ships are safeguarded against damage in the event of their being carried out of control.

The position is more hopeful in the case of the internal oscillations within the basins, deriving from seiches of periodicities of less than, say, six minutes. It was found from statistical considerations that if these are by any means reduced to 25 per cent. or less of the maximum magnitude known to have occurred in the worst years of Range-action, then ships are reasonably sure to be protected against damage.

An alternative to the solution which seeks to eliminate the internal oscillations, is one that seeks to tolerate them, but at the same time immunise shipping from damage. Any mooring technique which ensured permanently tight ropes, coupled with the use of shock-absorbing fenders, would provide a palliative solution to the problem without requiring the eradication of any essential features of the surging.

Attempts were made in experiments on the model of Table Bay Harbour to find a solution to the worst features of Range-action, which would be relatively simple and inexpensive, but comprehensive tests revealed that no simple solution of the problem apparently existed.

It was found that the only effective means of cutting down on the penetration of energy into the basins lay in the adoption of outer basin enclosures, within which the ground-swells could, at least be partially dispersed. But unless the enclosure was well chosen or carefully designed as to position and shape in relation to the harbour and the bay, it could become an " echo-chamber " for certain frequencies of waves, which by building up energy through resonance, might be capable of influencing the inner basins as much as ever.

The oscillations within a basin of irregular shape are so complicated that it is generally impossible to predict precisely what the behaviour will be, especially if that behaviour is dependent also on the interpretation of adjacent basins. It is here that model technique, properly applied, are of such inestimable value.

Experiments in 1946 eventually led to the isolation of one form of outer basin that fulfilled the requirements of a solution to the Range troubles in the Duncan Basin (Fig. 3). The Victoria Basin, unfortunately, was not amenable to the same treatment, largely owing to its unfavourable position in relation to the breakwater-shore oscillating system, but inasmuch as its importance was secondary to that of the Duncan Dock, this was not held to be too much of a disadvantage.

It cannot be claimed that the solution arrived at is necessarily the only arrangement possible: it is almost certain in fact that other alternatives can be devised, although some loss of efficacy may have to be conceded. The solution found may not even be a commercial proposition, owing to the entry of other factors into the design of future extensions.

At this time of writing development plans for Table Bay Harbour are under consideration based upon the general finding of the research that a breakwater protected outer basin is probably the best means of inhibiting Range trouble in the Duncan Dock.

Harbour Surging at Cape Town, South Africa—continued

General Conclusions.

Some of the principal conclusions to be drawn from the investigation as a whole may be enumerated in the following:

(1) The harbours of the world that are most likely to experience troubles in the form of Surge or Range-action will be those which lie on or near the tracks, in the line of approach, of the great atmospheric disturbances, such as the travelling depressions of the temperate zones and the cyclones of the equatorial regions, but more particularly those harbours which flank a wide expanse of the ocean in these regions, where depth and openness favour the propagation of long swells

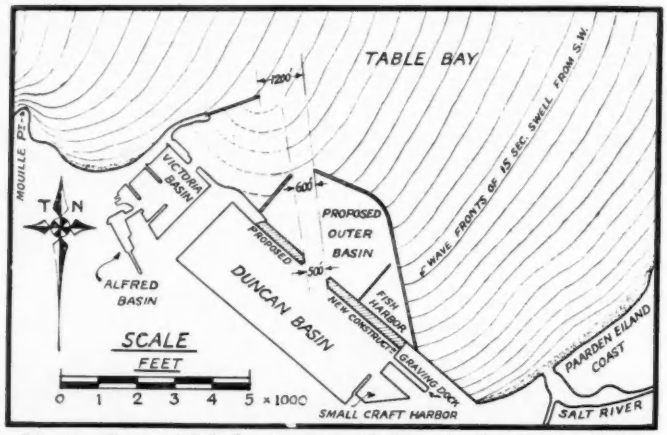


Fig. 3. Form of Solution to Surge Problem in the Duncan Basin, Table Bay Harbour.

(2) The bays and inlets along the coastlines in these areas will inevitably exhibit the phenomenon of seiches, the longer periodicities of which may even be dictated by the oscillations of the ocean within some hidden basin or canyon of the deep.

(3) If a bay conforms, in any sense, to a simple geometrical shape its natural periods of oscillation can probably be estimated with fair accuracy by mathematical means and some idea obtained as to the location of the nodes of the seiches.

(4) Bays which are fairly open will have a fundamental mode of oscillation in which the node will be found to lie at or near the mouth. Higher modes of oscillation will all have a node at the mouth in addition to other nodes whose distance apart will tend to lessen as the water shoals towards the head of the bay.

(5) Bays which are open to the sea through comparatively narrow entrance channels will probably exhibit, in addition to the modes of oscillation mentioned, other modes characteristic of fully enclosed basins of their particular shapes. The node of the fundamental seiche in a case of this kind will tend to lie near the middle of the lagoon.

(6) In the absence of a model study, the best means of identifying the seiches in a bay or estuary is by graphical determination of the expansion-fronts of incident and reflected waves.

(7) The graphical method will be found particularly valuable for orientating sea defence works and for rapid estimation of the likely repercussions that might derive from adoption of any harbour scheme.

(8) In general (other factors permitting), it will probably be found desirable for the avoidance of serious Range-action, to locate the harbour near the mouth of an open bay or near the middle of a semi-enclosed bay. By so doing the harbour works will not seriously interfere with the natural regime of the bay and will lie in a zone where modal lines are farthest apart. If the harbour is placed at the head of the bay where the modal lines of the many possible seiches tend to be concentrated, not only will it be subject to the worst effects of the loop ends of all the seiches, but it will tend to interfere with the natural order and will almost inevitably create a smaller " echo chamber " within which some of the seiches of the bay will resonate.

(9) If a harbour near the head of the bay is unavoidable, great care should be exercised in the location of the breakwater, lest the bight it creates should permit resonance of one of the seiches of the bay.

(10) It is desirable to ensure that the dimensions of the docks in the harbour are not such as to yield natural periods of oscillation which correspond with many of the external seiches. This may be difficult in a harbour near the head of a bay, owing to the numerous high-frequency seiches which may be engendered purely through the harbour creating a quasi-basin in that corner of the bay.

(11) As far as possible the length-breadth dimensions of harbour basins should be incommeasurable. Dimensions which are integral multiples of each other are likely to favour the development of seiches.

(12) It is the higher frequency seiches of the order of, say, two minutes period and less that should receive particular attention. These are the oscillations that are likely to give trouble with shipping.

(13) Perhaps the most efficient means of stifling the effects of Range-action of the higher frequency type is by creation of a chain system of basins, the outer ones of which act as chokes for absorbing the energy of the ground-swells.

(14) Model studies of wave action should preferably be conducted on models for which the distortion, or difference in the horizontal and vertical scales, is nil, or of as small an order as possible.

Acknowledgment.

The permission of the South African Railways and Harbours Administration and of the University of Cape Town to the publication of this paper is gratefully acknowledged.

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Increased Charges at U.K. Ports.

Applications were made recently to the Ministry of Transport for sanction to increase charges at the following ports : Bristol, Dundee, Greenock, Leith, Liverpool, London, Margate, Plymouth (Cattedown Wharves), Portsmouth, Sunderland and Tyne. These applications were examined by the Traders' Dock and Harbour Co-ordinating Committee. In general, they were based on increased cost of operation (especially wages), high cost of maintenance and improvements, and, in some cases, a decline in revenue from a reduced volume of trade. Some applications called for alternative proposals. In others, it was suggested that a review of the financial policy of the undertaking would avoid any increase in charges.

The Mersey Docks and Harbour Board's application for authority to increase harbour rates by 28 1/5 per cent., to increase other rates by 12½ per cent., and to re-impose outward coastwise town dues, was resisted because it was considered that the percentage increase sought was too high and that the re-imposition of the town dues would discriminate against coastwise shipping. Nothwithstanding the Committee's objection, the Minister authorised the Board's proposals.

In discussions with the Port of London Authority, the Traders' Dock and Harbour Co-ordinating Committee expressed the anxiety of shipowners and traders about the tendency of authorities to pass on automatically to users the full extent of increased costs, when in its view greater effort should be made to absorb them, at least in part, by improved methods of operation, such as the greater use of mechanical plant and economies in administration.

The Port of Halifax

The founding of Halifax was carried out under the direction of the Lords of Trade and Plantations in England. The City was named in compliment to George Montague, Earl of Halifax. The City's motto—E Mari Merces—meaning wealth from the sea, is synonymous with the development of the Port of Halifax operations that have taken place since the City was founded in 1749.

The harbour is the heart of Halifax. "Beautiful for situation," the phrase of the Psalmist for his sacred city, certainly fits the capital of the Province of Nova Scotia. Standing on Citadel Hill, which is the centre of Halifax, one can view the great land-locked harbour, where the old three-deckers used to swing at anchor. On the right extends a long inland stretch of the sea called the "Arm"; on the left is a second inner haven, twenty miles in circuit, named Bedford Basin.

Halifax was founded as a military necessity. It has been a pivotal point in five great wars. For over two centuries, the harbour has been the western centre of naval control for the North Atlantic, and the key to military control of the North-Eastern area of North America.

The City was built and first settled by men from disbanded regiments and paid-off ships. On its history, the pageantry of war has left its ineffaceable mark. There were mariners from Vernon's ships that captured Porto Bello, and soldiers who had fought at Fontenoy. The harbour saw the remnant of D'Anville's shattered armada creeping into the last act of its tragedy. It was alive with the sails of Saunders and Boscawen. It has floated every flag and every fashion of craft from 18th Century privateers to southern blockade-runners and the steel leviathans of modern war and commerce.

On the 21st June, 1749, the British sloop of war, "Sphinx," arrived in Halifax Harbour, having on board the Honourable Edward Cornwallis, Captain General and Governor-in-Chief of the Province of Nova Scotia. The first dispatch Governor Cornwallis sent to England contained a sentence which read: "All the officers agree the harbour is the finest they have ever seen." The shipping world of today stands in full accord with that statement made over 200 years ago.

Today the Port of Halifax stresses year round service, and to a Halifax man, Sir Samuel Cunard, must be given the credit of recognising that phrase and using it to its fullest extent. The result of his energy and foresight initiated the enterprise which led eventually to the formation of the famous Cunard Steam-Ship Company. To Cunard belongs the honour of being the first man to bridge the Atlantic with a line of steamers.

The "Britannia," a wooden paddle steamer, inaugurated the service of the British and North American Royal Mail Steam Packet Company. She sailed from Liverpool on July 4th, 1840, and arrived in Halifax 12 days later.

Halifax, because of its strategic location, has played an important part in the history of Canadian shipping. In the last three years 12 new steamship lines have made Halifax a port of call.

Aerial view of Halifax, showing the extensive waterfront of the Harbour, and the City proper. The following are the main waterfront properties: 1, Citadel; 2, "Arm"; 3, Bedford Basin; 4, Ocean Terminals; 5, Sea Wall; 6, Cold Storage Terminal; 7, Grain Elevator; 8, Private Piers; 9, Deep-water Terminals; 10, H.M.C.S. Dockyard; 11, Halifax Shipyards and Drydock; 12, Richmond Terminals.

Port of Halifax—continued

The first commerce in Halifax harbour came from Newfoundland, the West Indies and the American Colonies. Britain became conscious of the extent of Canada in the days of Confederation. Winter tied up the St. Lawrence River outlet for a vast hinterland for four and one-half months of every year. So the Intercolonial Railway was built, to provide an all-Canadian line of communication and a tidewater place of embarkation on British territory.

World connections of Halifax harbour provide direct access to the eastbound trade lanes of the North Atlantic which serve Great Britain, Scandinavia and Continental Europe. Other world connections are the trade routes to the East Indies and Far East; the southbound trades to the British West Indies and South American countries; and the eastbound trades to the Mediterranean.

Port facilities in the harbour combine efficiency with economy. They are so designed as to serve most effectively the majority of port users and, in particular, accomplish their main purpose of enabling cargo to be transferred with minimum delay from or to deep-sea craft, to or from coastal craft, railway cars and transport trucks.

This activity is well planned and managed and diligently performed. The unloading and loading of ships is co-ordinated with the loading and unloading of railway cars and transport trucks so as to ensure that no bottle-neck will develop and cause congestion and delays to traffic. Mechanised methods are used wherever practical to increase port efficiency and lower overall costs.

In the matter of transportation services, there are regular and frequent sailings to many overseas ports, and ships using the port are of such design, capacity and speed as to meet all reasonable traffic requirements.

Coastal shipping meets satisfactorily all demands of traffic, and Halifax is the centre of all coastal distribution for all shore ports in the Maritime Provinces.

Rail and highway transport services are adequate, efficient, dependable and provide ship-side pick-up and delivery of shipments. The harbour railway, which has 31 miles of track, serves nearly all berths and transit sheds, and is operated by the Canadian National Railways. The port is also served by the Canadian Pacific Railways through the Dominion Atlantic Railway.

To provide a speedy service to handle export and import traffic moving between Halifax and central and western canada and the United States, the Canadian National Railways maintain three fast manifest freight trains daily in each direction. In addition it operates an average of ten regular freight trains each day, and if the need arises is prepared to operate others.

The Dominion Atlantic Railway draws products from the harbour to the markets of central and western Canada, and helps haul the nation's exports to the harbour docks.

Freight handling by air transport is rapid and efficient. Economical flight service by Trans-Canada Airlines ensures prompt delivery and satisfaction. At present two sites are under survey regarding a new air terminal which is to be located in the Halifax area. When the proposed new airport is selected and constructed the importance of Halifax on the Canadian air traffic map will be greatly increased, in that, present air freight handling conditions will be improved to better the efficient service now in effect.

As Canada has developed its resources and productive capacity, Halifax has become one of the great funnels through which emigrants and goods have entered the Dominion, and the products of the country's resources have been transferred across the seas.

To accommodate passenger traffic the construction of a new, modern Customs annex is to begin shortly and will greatly facilitate the handling of passengers and their baggage. Connected to the piers by an underpass, all functions of the new annex will be geared so that passenger traffic is maintained at the same level in peak periods, as in the normal flow.

Contributing to port efficiency is the accessibility available to all shipping. The existence of good pilotage, tug services where necessary, and efficient aid to navigation in the form of lights, buoys, radar, and reporting stations for direct communication of vessel movements, weather and other shipping intelligence, enable ships to proceed from open water into the harbour and to their assigned berths without delay.

The port has a high standard of efficiency that ensures quick turn-round, and the fact that Halifax has the shortest distance, port to port, from Europe, South Africa, Straits Settlements, India or Hong Kong, of any port on the Atlantic Coast, assures the fast and efficient handling of cargo, and gives a service to shippers that is unsurpassed anywhere.

From information received with reference to handling cargo, Halifax, in many respects, has shown a high degree of efficiency. The labour problem in connection with working agreements with local stevedores is well handled, and is considered one of the best arrangements in Eastern Canada. Yearly meetings are held between stevedores executives and steamship interests, and agreements are drawn up in the best mutual interest of all concerned with the operation and use of the port.

Due to the growing export movement of Canadian grain, an addition is being built to the grain elevator which at present has a capacity of 2,200,000 bushels. The new addition will increase the capacity to 4,250,000 bushels.

The cold storage terminal is a modern fireproof structure with about 1,655,350 cubic feet of storage space completely fitted with freezing and storing equipment and is serviced by eight railway tracks. Enlarging of the port cold storage equipment and buildings is now in the planning stage, and it is expected that an announcement will shortly be made concerning the modernisation of the present facilities.

Halifax harbour is approached directly from the ocean by a channel with a minimum depth of 50ft. at low tide. It is open to navigation the year round, has wide turning areas and virtually no currents. It is land-locked, well sheltered, and the rise of tide is 6½ feet at springs, and 5¼ feet at neaps.

Nearly all ocean-going shipping uses the National Harbours Board terminal facilities, where some 30 berths are available on eight main piers and wharves, having a combined berthing length of about 17,000 lineal feet. There are 17 transit sheds with an aggregate floor area of 1,241,000 square feet, all of which are served by convenient track and siding accommodations.

One of the outstanding facilities of the National Harbours Board is the sea wall. This facility includes berths 20-21-22, each over 600ft. in length, and in a continuous straight line, which together form one of the finest landing quays in the world. The total length of 2,007-ft. is of concrete construction with 45-ft. of water at low tide. There are five lines of railway tracks along the whole length of these sheds.

In addition to the National Harbours Board piers there are 40 other docks and wharves under private management.

Heavy lift equipment by companies located on the waterfront provide excellent service. Halifax shipyards has the largest crane which will handle up to 75 tons lifting capacity.

Imperial Oil Limited has convenient oil bunkering and storage facilities which are served by the railways. Atlantic Trawlers Limited provide excellent ship-side service in the unloading and loading of oil such as palm, coconut, linseed, etc., to and from railway cars.

There are three coal berths available at the port and five coal barges, and the average quantity of coal per hour from barge is 100 tons, when delivered in the open bunker spaces (not including trimming) and average quantity per hour when vessels are at berth is 250 tons when delivered in open spaces (not including trimming).

Halifax shipyards can render all services relative to ship construction and/or repairs; they can construct any type of vessel up to 15,000 tons, with attendant machinery, execute repairs and/or maintenance of all types of engines, and carry out hull repairs of vessels up to 25,000 tons. It has a graving dock of 568-ft. long and 102-ft. wide with a 30-ft. depth oversill, also a floating dock capable of lifting a vessel of 25,000 tons or thereabout.

On the east side of the harbour, on the Dartmouth shores, shipyards also have a plant fully equipped which can render efficient service to vessels of 5,000 tons or less. Also on the Dartmouth site are six marine railways, two of which are capable of hauling out vessels up to 4,700 tons deadweight.

Calculation of Earth Pressures

New Methods of Investigation

By J. Brinch Hansen, Dr. Techn.

Foreword.

The book entitled "Earth Pressure Calculation" by Dr. J. Brinch Hansen, a brief review of which appeared in the November, 1953, issue of this Journal, has excited considerable comment. In view of the interest which has been aroused, we are printing the following paper which is, more or less, an abstract of the book. The author is Chief Engineer to Messrs. Christiani & Nielsen, Copenhagen, and was awarded his degree of Doctor of Technology for the thesis which is put forward in the book. (Published by The Danish Technical Press, Copenhagen).

The Defence Proceedings for the Technical Doctor's degree conferred upon Dr. Hansen are also of some interest, and an abstract of them follows the paper.

1. Introduction.

In most earth pressure theories it is assumed that a state of failure exists in the earth. As criterion of failure, the so-called Coulomb's law is practically always used; it states that the shear stress τ in a plane, on which a normal stress σ acts, cannot exceed the value:

$$\max. \tau = c + \sigma \tan \varphi \qquad (1)$$

c (the cohesion) and φ (the friction angle) are assumed to be constants for the soil in question. The same applies to the effective unit weight γ. Two extreme cases are especially important, namely those concerning frictionless soils ($\varphi = 0$) as fully saturated clays, and cohesionless soils ($c = 0$) as sand and gravel.

On a small element of a wall, or any other structure in contact with the earth, act a normal earth pressure e and a tangential earth pressure f. In analogy with Coulomb's law it is assumed that f cannot exceed the value:

$$\max. f = a + e \tan \delta \qquad (2)$$

One extreme case is that of a perfectly smooth wall, for which $a = 0$ and $\delta = 0$. The other being that of a perfectly rough wall, for which $a = c$ and $\delta = \varphi$.

2. Figures of Rupture.

A curve, for which τ and σ in any small element satisfy the failure condition (1), is called a rupture-line. A line making angles of $90° \pm \varphi$ with a rupture-line is sometimes called a pseudo-rupture-line. The total system of rupture-lines is termed a rupture-figure, and of such the following three main types exist.

(1) Line-ruptures, in which the condition of failure is fulfilled only for the points on a certain curve. The so-called elastic zone of earth above this curve slides along the rupture-line which, consequently, must be a circle (or a straight line). In Fig. 1, a concave line-rupture (A) and a convex line-rupture (X) are shown.

(2) Zone-ruptures, in which the condition of failure is fulfilled for any point within a certain area. In this so-called plastic zone the deformations consist of slidings and strains. In Fig. 1 are shown a Rankine-zone (R) and a Prandtl-zone (P); the latter is characterised by a singular point, in the vicinity of which the curvature of one set of the rupture-lines approaches infinity.

(3) Composite ruptures, which consist of at least two zones. The corresponding rupture-lines may either meet each other flush (f), or at an angle (a), or at the wall (w), or they may be completely separated (s). Four characteristic composite ruptures are shown in Fig. 1, together with their denominations.

That the above-mentioned rupture-figures are not merely theoretical but actually occur in nature, can be demonstrated by turning a rigid wall about a given rotation centre and photographing the movements of the sand grains. Four such photographs are reproduced in Figs. 2-5. The small circle indicates the rotation centre, and the arrow the direction of the rotation. Two arrows and no circle indicate a translation. Finally, the black curve shows the limiting rupture-line as found by a purely theoretical calculation, by means of the author's methods.

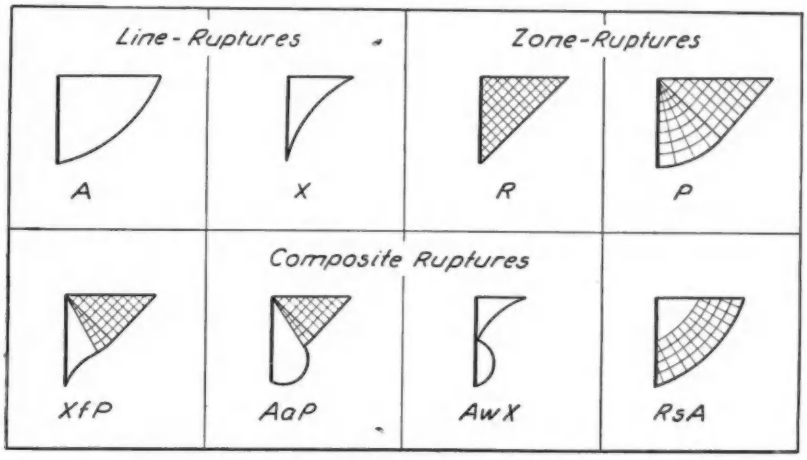


Fig. 1. Figures of rupture.

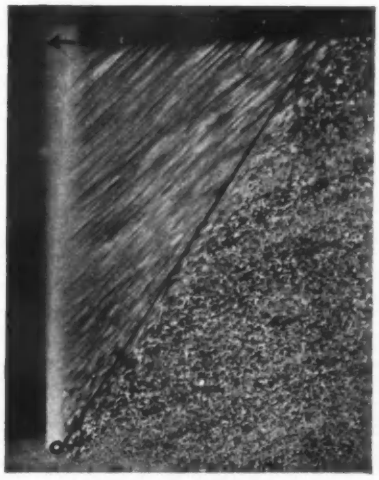


Fig. 2. Actual rupture R.

3. Deformations and Movements.

The classical earth pressure theories of Coulomb and Rankine are actually more or less approximate means of calculating zone-ruptures. Their most severe limitation is that they operate with straight rupture-lines only. This limitation does not exist in the mathematical theories of plasticity, but also these theories have so far only been applied to zone-ruptures.

Now, it is a noteworthy fact that in the plane case the stresses in a zone-rupture may be fully determined without any investigation of the corresponding plastic deformations. This fact may be responsible for the widespread but erroneous belief, that the earth pressure on a wall is independent of the movement of the wall (apart from the distinction made between active and passive pressures).

Actually, the movements of the wall and the earth must of course be compatible, and, if the possible deformations in a zone-rupture are investigated, it will be found that usually a zone-rupture can only occur, when the rotation centre for the wall is located below its foot. For other locations of the rotation centre line-ruptures or composite ruptures must occur, and this means that the earth pressure on a wall must depend on the type of movement performed by the wall.

An ordinary retaining wall will usually rotate about a point below itself. As the corresponding rupture-figure in the backfill is a zone-rupture, in which the actual rupture-lines are approximately straight, this explains the fact that the methods of Coulomb or Rankine have served rather well for the design of such retaining walls.

However, these classical methods have, for want of more suitable methods, also been used to design other structures such as, for example, free or anchored sheet walls. The fact that very misleading results have been

Calculation of Earth Pressures—continued

obtained in this way, is easily explained when it is noted that, in the state of failure, the mentioned structures must rotate about points located above their foot. This means that zone-ruptures cannot occur, and as the actual rupture-lines are far from being straight, the classical methods are useless in such cases.

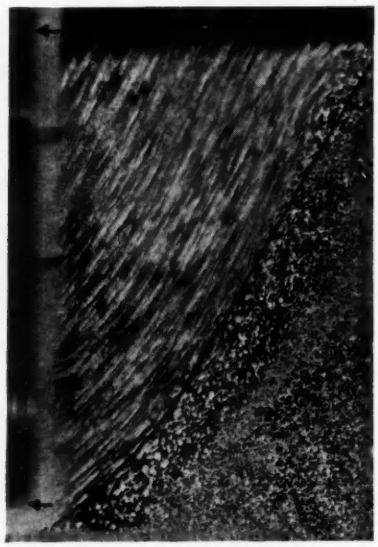


Fig. 3. Actual rupture P.

4. Calculation Methods.

Methods for calculating a line-rupture have only been developed rather recently. The following two different methods are known:

(1) The extreme-method (Rendulic 1940) employs as an approximate rupture-line a logarithmic spiral, in which the radius-vectors make angles φ with the corresponding normals (see Fig. 6). The moments about the pole of the spiral are taken of all forces acting upon the earth mass above the spiral. This procedure eliminates all unknown stresses in the rupture-line (because they are directed towards the pole) and enables thus the determination of the earth pressure, provided that its direction (δ) and pressure centre (z) are known. When such a calculation is made for different spirals, the critical spiral may be determined as the one making the active earth pressure a maximum, or the passive a minimum. For any given pressure centre it is thus possible to calculate the corresponding magnitude of the earth pressure. but, as the spiral is kinematically impossible rupture-line, the rotation centre for the wall cannot be indicated. This is the most serious shortcoming of the extreme-method.

(2) The equilibrium-method (Ohde 1938) may employ as a rupture-line either a circle or a spiral, but the use of a circle has the advantage that the rotation centre for the wall is then given as the normal projection of the centre of the circle on the wall (see Fig. 7).

If the internal stresses in the rupture-line are known, the 3 equilibrium conditions for the earth mass above the rupture-line will enable the determination of 3 unknown quantities. With a given δ and z, we are able to find E and 2 geometrical parameters of the critical rupture-line which, in this case, may be a circle or a spiral. With a given δ and x we can, for a circular rupture-line, find E, z and one independent geometrical parameter of the circle (e.g. its radius).

The necessary knowledge of the stresses in the rupture-line may be obtained by means of the so-called Kötter's equation (1903):

$$\frac{d\tau}{ds} + 2\tau \frac{dv}{ds} \tan\varphi + \gamma \sin\varphi \sin(v + \varphi) = 0 \qquad (3)$$

in which s is the arc length along the rupture-line, and v the angle between the tangent of the rupture-line and the horizon.

For any given rupture-line the differential equation (3) can easily be integrated, but the stresses cannot be calculated unless they are known in advance at one point, e.g. at the intersection between rupture-line and ground surface. However, a unique boundary condition can only be indicated, either when the rupture-line makes a certain angle with the ground surface, or in the special case of cohesionless earth with an unloaded surface. This fact constitutes a rather severe limitation of the equilibrium-method in its original form.

However, the author has succeeded in making the equilibrium-method generally applicable, by proving that the extreme-method and the equilibrium-method will give identical results, when a certain boundary condition is used in the latter. Incidentally, this general boundary condition may be obtained in the following way: Consider the stresses acting upon a small triangular element between the boundary, the rupture-line and a pseudo-rupture-line, and express that the resultant perpendicular to the pseudo-rupture-line should be zero.

By means of the thus generalised equilibrium-method, it is possible to calculate the earth pressures corresponding to line-ruptures, zone-ruptures and the simpler composite ruptures. This means that the earth pressure can be determined, corresponding to any given rotation centre for a rigid wall, and also (approximately) for a wall in which one or more yield hinges have developed.

It will sometimes be found that more than one rupture-figure is kinematically possible, corresponding to a given movement of the wall. In such cases the critical rupture-figure will be the one, for which the work done by the earth pressure (acting upon the earth) is a minimum.

5. Pressure Diagrams.

For the total normal earth pressure E, and its moment Ez about the foot of the wall, the following general formulae apply, when h is the height of the wall and p the unit surcharge:

$$E = \frac{1}{2}\gamma h^2 \lambda + ph\rho + ch\varkappa \qquad (4)$$

$$Ez = \frac{1}{2}\gamma h^3 \lambda\eta + ph^2\rho\Theta + ch^2\varkappa\xi \qquad (5)$$

For zone-ruptures, the distribution of the earth pressure can be determined with any desired accuracy, but this is unfortunately not possible for line-ruptures or composite ruptures. However, the author has tentatively proposed a simple pressure distribution as shown in Fig. 8. A pressure jump is assumed to occur at a height ωh, and the unit earth pressures above and below this point respectively are given by the following formulae, in which d indicates the depth below ground surface:

$$e^x = \gamma d\lambda^x + p\rho^x + c\varkappa^x \qquad (6)$$

$$e^y = \gamma d\lambda^y + p\rho^y + c\varkappa^y \qquad (7)$$

The left diagram in Fig. 8 corresponds to a positive rotation of the wall (by which the angle between wall and ground surface is increased), whereas the right diagram corresponds to negative rotation (by which the said angle is decreased). The formulae (6)-(7) will sometimes yield negative earth pressures, but it is recommended that such negative pressures be disregarded.

The dimensionless constants in the equations (4)-(7), as well as the relative height ω of the pressure jump, are functions of the relative height ξ of the rotation centre. For the important practical case of a vertical wall and a horizontal ground surface the author has indicated these functions in a series of graphs in the Appendix of his book. As an example, Figs. 9-10 show the graphs for ω $\varkappa_x$ and $\varkappa_\gamma$ in the case of frictionless earth ($\varphi=\theta$). In this case the constants λ and ρ are equal to 1.

The formulae (6)-(7) are principally valid for homogeneous earth but may, as an approximation, also be used in the case of layered earth. The dimensionless constants to be used at any depth should then correspond to the layer in question, and the term γd should be substituted by the overburden pressure. In the case of partly submerged earth, the unit weights γ for the submerged layers must be reduced for uplift, and the water pressures proper must be added to the earth pressures.

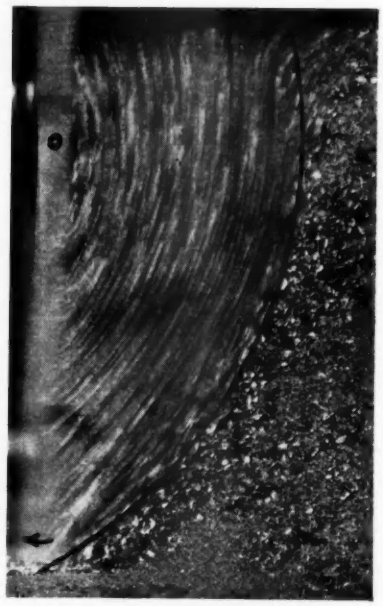


Fig. 4. Actual rupture A.

It will be seen that, with the aid of the author's graphs, the determination of the

Calculation of Earth Pressures—continued

Fig. 5. Actual rupture XfP.

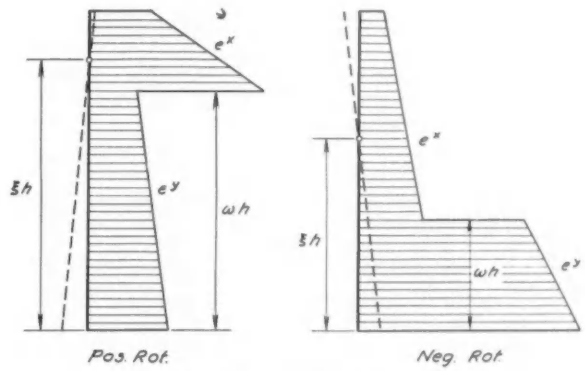


Fig. 8. Earth pressure diagrams.

earth pressure diagram is hardly more complicated than by means of the classical methods.

6. Design Principles.

In order to design a structure subjected to earth pressures, it is necessary to first determine the type of movement to be performed by the structure in the state of failure. In some cases this movement is given (example: a retaining wall must rotate about a point below itself) or may be chosen (example: an anchor slab yields the maximum resistance

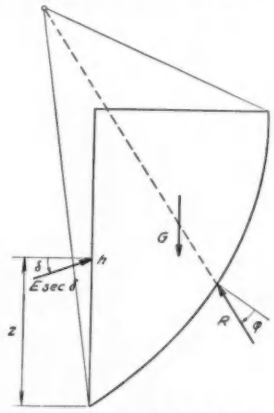


Fig. 6. Extreme-calculation.

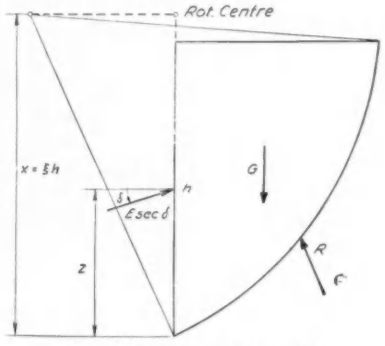


Fig. 7. Equilibrium-calculation.

by a translation) but in other cases it involves an unknown quantity to be determined by the calculation (example: a free sheet wall rotates about a point at an unknown height above its foot).

More complicated structures may fail in different ways (example: an anchored sheet wall may fail, either because the anchorage yields, or, because a yield hinge develops in the wall proper). In such cases, any one of the possible states of failure may be chosen as the basis of a safe design, as it can be shown that, when the structure is designed accordingly, it cannot fail in any other way. The choice of a suitable state of failure will then mainly be guided by economical considerations.

As soon as the movement of the structure has been fixed, the corresponding earth pressures can be calculated, and the actual dimensions of the structure are then determined so as to satisfy the equilibrium conditions for the structure proper in the state of failure. The necessary safety against failure is obtained by dividing the actual shear characteristics c and tan φ by suitable safety factors, and carrying out the calculation with the reduced values. Further, as " permissible " stresses for the structural materials, their ultimate or yield strengths divided by other safety factors are used.

In his book, the author has applied the new methods to the design of retaining walls, anchor slabs, free sheet walls, anchored sheet walls, fixed sheet walls, braced walls, double sheet walls and cellular cofferdams. In principle, the methods are applicable to earth with cohesion or friction or both, to ground surfaces with any slope and surcharge, and to walls with any inclination or roughness. However, the practical calculations become simplest in the case of vertical walls and horizontal surfaces, at the graphs in the book will then give the earth pressure constants direct.

7. Example of Design.

As a simple example of a design according to the new method, the anchored sheet wall in Fig. 11 shall be considered. It is assumed to be perfectly smooth, and is driven into soft clay ($\varphi = 0$) with an actual cohesion (undrained shear strength) of 3 t/m². By division with a safety factor 1.5 it is found that the calculation should be made with c = 2 t/m². The effective unit weight of the clay is $\gamma = 1.7$ t/m³ above water level, and $\gamma' = 0.7$ t/m³ below. The surcharge is $p_1 = 2.75$ t/m².

The levels of the anchors and the ground surfaces at both sides of the wall are given (see Fig. 11), but the driving depth h_2 must be determined so as to satisfy the equilibrium conditions for the wall.

As the soft clay is only able to exert rather moderate passive pressures on the wall, the most economical design will, in this case, be obtained by considering the state of failure which requires the smallest possible passive pressure. This corresponds to a rotation of the wall as a rigid body about the anchor point.

As soon as a driving depth has been estimated, the relative heights of the rotation centre are known ($\xi_1 = q : h_1$ and $\xi_2 = q : h_2$), and the graphs in Figs. 9-10 yield then the constants necessary for determining the earth pressure diagrams (see Fig. 11). It is then investigated, whether these pressures satisfy the moment equation about the anchor point. If not, the estimated driving depth must be changed and the calculation repeated, until satisfactory agreement is obtained. After this, it is easy to determine the anchor pull and the moments in the wall.

In the case shown in Fig. 11, it is found (by trial) that a driving depth of 2.9 m. will ensure the fulfilment of the moment equation about the anchor point. The corresponding anchor pull is 36.1 t/m, and the numerically greatest moment in the wall 15.8 tm/m (at anchor level).

If both the wall and the anchors are to be made of steel 37, with a yield stress of 2400 kg/cm², the " permissible " stress is found, by division with a safety factor 1.2, at 2000 kg/cm². Consequently, the necessary section modulus for the sheet wall is 790 cm³/m, and the necessary section area of the anchor bars 18.05 cm²/m.

When the wall has been designed for a rotation about the anchor point as described, it is easily shown that it cannot fail in any other way. If the anchorage should start yielding, this would decrease the active pressure on the upper part of the wall and increase it on the lower part. As a result, the anchor yield would stop and the foot of the wall would yield instead, just as assumed in the design. If a yield hinge should start developing in the wall, this would decrease the active pressure on the central part of the wall and increase it on the lower part. As a result,

Calculation of Earth Pressures—continued.

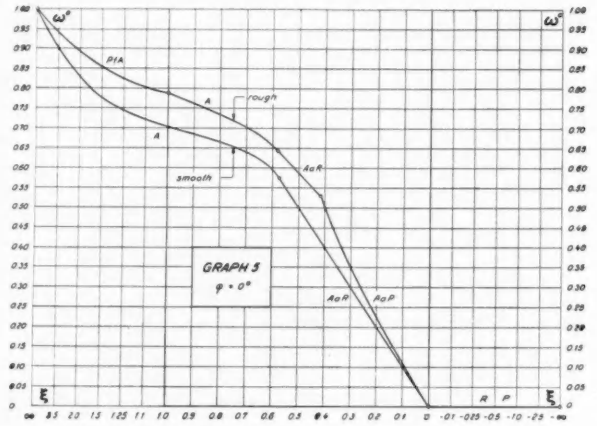


Fig. 9. Graph for ω ($\varphi = 0$).

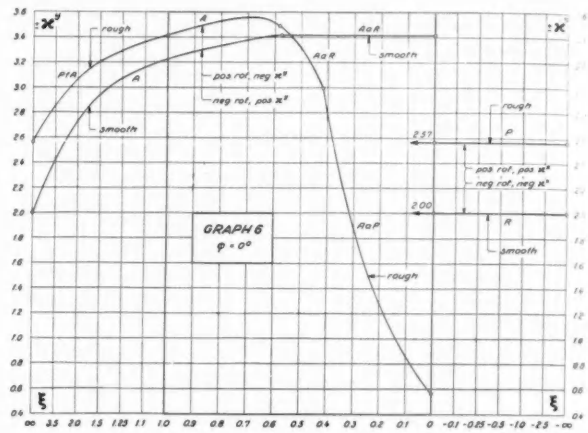


Fig. 10. Graph for x^x and x^y ($\varphi = 0$).

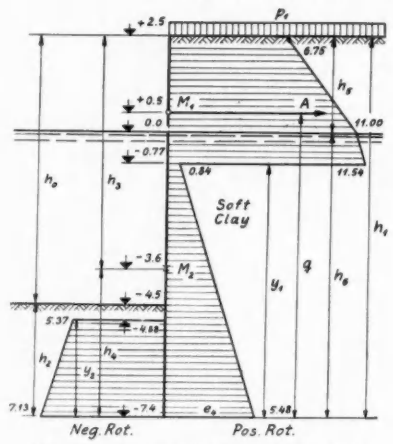


Fig. 11. Anchored sheet wall in clay.

the yield in the wall proper would stop and the foot of the wall would yield instead, just as assumed.

8. Conclusion.

It might be queried whether it is correct to design an earth supporting structure on the basis of a state of failure as described above, or whether the design should be based upon the stresses occurring under actual working conditions. However, in the latter case, theoretical calculations would become extremely complicated so that, in practice, only empirical methods may be used. Such methods have been proposed by Tschebotarioff (1948) and Rowe (1952), but as with all empirical methods their practical application is limited to the structures and conditions investigated in the basic tests.

The theories of rupture or failure developed by the author have the advantages of being comparatively simple and generally applicable. Their main shortcoming seems to be that they cannot give any information concerning the stresses and deformations under actual working conditions. However, this is probably less important for earth supporting structures than for any other type of structure, as earth supporting structures can usually, without detrimental effects, stand up to deformations which would be definitely unallowable for practically any other structure.

A comparison between the new theories and practical experience has as yet only been carried out in a few cases. However, the new theoretical methods seem to agree rather well with the more reliable empirical methods, in such cases where the latter can be applied. Moreover, the connection established between the generalised equilibrium-method and the well-known extreme-method should be a safeguard against serious errors, as the extreme-method has proved to be in excellent agreement with practical experience.

Report on the Defence Proceedings for the Technical Doctor's Degree.

On the 25th of September last, Mr. J. Brinch Hansen defended his doctor's thesis on " Earth Pressure Calculation." The proceedings took place in the Assembly Hall of The Technical University of Denmark, and were conducted by Professor P. H. Bendtsen, Dr. techn.

The five official opponents were all unanimous in their opinion of the extremely high standard of the thesis, in which nothing of any real importance could be seriously criticised. In spite of persistent attempts through more than four hours, the opponents were unsuccessful in weakening Mr. Brinch Hansen's theories and calculation methods on any principal point.

It is not possible to give here a detailed report on all the questions discussed. Only the most important shall, therefore, be mentioned.

The proceedings commenced with a short orientation given by Mr. Brinch Hansen for the benefit of those in the audience who had not read the book. Mr. Brinch Hansen concluded by drawing attention to a miscalculation on p. 209. In the line commencing with the words " Danish Rules," the proper figures should be: 1.8 - 8.0 - 1300 - 6.2 - 9.0 - 1600 - 565.

The first opponent, Professor H. Lundgren. then spoke as follows:

" This book, which is to-day presented for public discussion, is the result of a very impressive piece of work. With regard to originality, this thesis definitely stands in the first rank among the Danish doctor's theses on the subject of civil engineering. The greatest merits are the following:

A critical analysis has been made of all the most important of the hitherto known theories dealing with earth pressure problems. We have now a perfectly clear picture of the advantage and disadvantages of the different theories and can well understand why some of these may sometimes produce completely misleading results.

Experience and evidence are, of course, absolutely essential in soil mechanics, but without theories there is actually no possibility of further development. On this background the present thesis must be considered extremely important. Mr. Brinch Hansen has succeeded in creating a combination between the extreme-method and the equilibrium-method by means of his particular boundary condition. Herewith a tool has been produced which, as regards earth pressure, stability and bearing capacity problems, is by far more powerful than any previously known.

It must further be mentioned that, with the aid of this tool. Mr. Brinch Hansen has succeeded in treating, in addition to the known simple problems, innumerable problems, which hitherto could not be solved rationally. This has required the employment of many completely new figures of rupture."

Professor Lundgren mentioned the minimum condition regarding the choice between different rupture-figures, and the application of the main safety factors to the shear constants of the soil. In his criticism he raised the question of whether the design should be based on an investigation of the deformations under working conditions, or whether it should correspond to a state of failure or rupture with reduced strength of the soil. He declared himself to be a supporter of the rupture theory as far as most structures were concerned, but at the same time drew attention to the possibility that a progressive development of the rupture might result in a reduction of the intact shear strength, at least in part of the rupture-line.

To this, Mr. Brinch Hansen replied that if the theory of rupture was to be applied at all, it should be on quay walls, retaining walls and other structures subjected to earth

Calculation of Earth Pressures—continued.

pressures, because such structures could, without being rendered useless, stand up to deformations which would be quite hopeless in the case of most other structures. He maintained, therefore, that he would without hesitation apply the theory of rupture to such structures, at least in the case of sand. On the other hand, however, he would warn against an uncritical use of the theory of rupture in cases of clay with so high a shear strength that very small active or large passive pressures would be found by the calculation. The reason for this being that clay after a time seems to react more as a viscous fluid than as an ideal plastic material. With regard to progressive rupture, he stated that experience has shown that the intact shearing strength could safely be used in stability investigations. The same would probably also be the case in earth pressure problems.

With reference to the correction mentioned by Mr. Brinch Hansen in his introductory remarks, Professor Lundgren pointed out that this would mean that the agreement with the Danish Rules would not be quite as good as previously indicated. With the proposed safety factors the new methods might often lead to somewhat larger dimensions than would correspond to the Danish Rules for anchored sheet walls. In reference to this, he criticised that definite safety factors were given, and raised the question as to how Mr. Brinch Hansen would explain the fact that sheet walls, calculated in accordance with the Danish Rules, had proved satisfactory, although according to his methods of calculation they must possess a nominal safety of less than 1.25, in some cases probably even less than 1.0.

Mr. Brinch Hansen replied that, first, it is possible that these sheet walls stand with very little actual safety; second, that most of them are calculated on the basis of estimated friction angles, which are probably usually somewhat on the safe side; third, that recent investigations seem to indicate that hitherto both triaxial tests and direct shear tests have been wrongly interpreted, so that the actual friction angles are probably about 5° greater than corresponding to the conventional interpretation of these tests.

The next opponent, Professor K. W. Johansen, in his criticism first stated the basic conditions in any statical problem: the statical, the kinematical and the physical. He then tried to prove that the extreme-method and the equilibrium-method must always be identical, as they are both based on the same basic conditions, Mr. Brinch Hansen pointed out, however, that both methods are approximations, so that each of them normally only fulfils a part of the basic conditions. This explains why a fundamental difference may exist between the two methods.

In connection with the physical conditions, Professor Johansen drew attention to an almost forgotten semi-empirical theory of elasticity, developed by Boussinesq, who considered the physical properties of earth as being intermediate between those of a fluid and a solid. He further mentioned that Prager's theory of dilatation, which Mr. Brinch Hansen has rejected as being inconsistent with experimental facts, is also mathematically incorrect, as it is based on the concept of plastic potential which, according to Professor Johansen, cannot be applied to a material with internal friction. Among other things, he asked if rupture-figures could not occur in combination with the formation of a cavity in the earth.

Mr. Brinch Hansen replied that in cohesionless sand without capillary stresses, nothing of this nature could occur. In earth with cohesion, on the other hand, such rupture-figures were possible, either through the formation of tension cracks in the earth proper, or through the fact that part of the wall may move away from the earth.

Professor Johansen was of the opinion that certain phototechnical indications regarding Mr. Brinch Hansen's model tests were lacking, and at the same time pointed out that the photographic figures of rupture might differ somewhat from the actual ones, due to the friction along the glass walls of the test box.

The next opponent was Dr. J. F. Rüdinger, who had done a great deal of work in checking the theoretical assumptions of the thesis and in calculating a number of different rupture-figures. He said his criticism would apply to minor points only. He had considered the case of a partial surcharge, which can easily be solved by means of the classical methods, and he was of the opinion that Brinch Hansen's equilibrium-method would fail in this instance, as the boundary-stress was indeterminable in the case of a rupture-line starting from the point of surcharge jump.

Mr. Brinch Hansen maintained, however, that his method could solve this problem perfectly, as in place of the unknown boundary stress the location of the starting point of the rupture-line was known.

Dr. Rüdinger suggested using, in place of Mr. Brinch Hansen's special boundary condition, the mathematically correct condition by assuming the rupture-line to make a sharp turn so as to intersect the boundary under the statically correct angle.

Mr. Brinch Hansen admitted that the problem could also have been solved in this manner. He had been fully aware of this possibility, but had preferred his own boundary condition for the following reasons. It is simpler and in many cases gives more consistent results: it implies no kinematical deficiencies, and its connection with the extreme-method ensures its reliability.

In answer to Dr. Rüdinger's question, whether it would not be necessary to always employ the largest dimensions found by investigating various states of failure, Mr. Brinch Hansen reiterated his proof that it suffices to investigate one state of failure only, and emphasised that all dimensions should be determined corresponding to the same state of rupture.

Finally, Dr. Rüdinger explained that he had investigated a zone-rupture with circular rupture-lines and had found that it could occur for rotation centres located at certain heights above the wall. He would therefore suggest that such zone-ruptures be used for the rotation centres in question.

Mr. Brinch Hansen, however, rejected this proposal, stating that the circular rupture-line is only an approximate means of calculating the earth pressure, whereas in an actual zone-rupture the part next to the ground surface is always a Rankine-zone.

Dr. Rud. Christiani then spoke as the last opponent ex auditorio. After congratulating Mr. Brinch Hansen on his thesis and on the amount of recognition he had received, Dr. Christiani expressed the hope that, in using Mr. Brinch Hansen's new calculation methods, one would still bear in mind the practical experience gained, and remember that the structure must not only be strong enough, but also economical.

Professor A. E. Bretting, former Chief Engineer of the Central Designing Office, then spoke as the last official opponent. He agreed with Mr. Brinch Hansen that the kinematical conditions were of decisive significance in the choice of rupture-figures and stated, that these conditions had been excellently explained in the thesis. Professor Bretting had mainly concentrated his efforts in a thorough checking of the theoretical basis, but had found it to be correct on all important points. His last doubts had been fully removed by Mr. Brinch Hansen's clear answers to the preceding opponents' criticisms and questions.

On the other hand, Professor Bretting was of the opinion that the thesis was exceedingly concentrated. as much of the information had been given in the nature of postulations, which, however, upon closer investigation proved to be well founded. He warned against a general application of the safety factor 1.5 in clay, as, in his opinion, the deformations would then frequently prove to be decisive for the dimensions.

In answer to Professor Bretting's question as to why two different sets of sign rules had been employed for the cohesion, Mr. Brinch Hansen replied that the treatment of composite ruptures, in which both active and passive pressures may be present at the same time, had made this necessary. He had, however, tried to remedy this by stating, wherever any doubts could arise, which sign the cohesion should have in the formulae in question.

Port of Liverpool Changes

Sir Rex Hodges, general manager and secretary of the Mersey Docks and Harbour Board, is to retire on March 21. He will be succeeded by Mr. Francis H. Cave, his present deputy. Sir Rex joined the Board in July, 1935, and was appointed general manager and secretary in July, 1941. Before entering the Board's service he was with the Cunard Line at Liverpool in control of staff and labour affairs. Then he moved to the Anchor Line as general manager at Glasgow. He was North West Regional Port Director in 1945-46 and is now chairman of the National Dock Labour Board (Liverpool Group).

Mr. Francis H. Cave has been with the Board since 1926, and during the last war was responsible for the clearance of dock quays and the rapid flow of cargo through the port. In 1946 he was appointed assistant general manager and secretary.

Correspondence

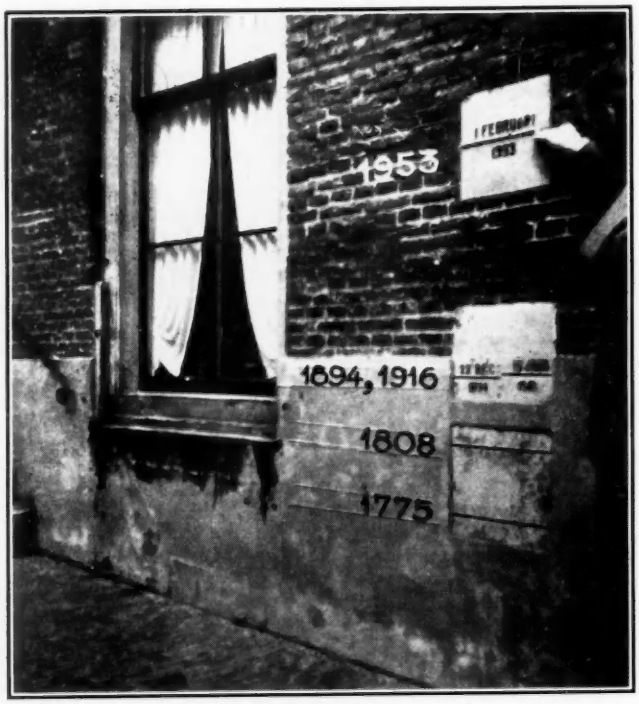
To the Editor of *The Dock and Harbour Authority.*

Dear Sir,

Fatal Beliefs on Flooding Levels

The height of the 1953 flood will be put on all drawings of banks, docks, locks and other marine structures in England, Belgium and Holland. These are the well known "S-F lines." Will these lines ever be superseded? Commander Farquharson told the Institution of Civil Engineers and its foreign guests a few months ago that they may well be.

The belief that the new " S-F line " is a magical line above which hardly any flood will come could be fatal. For Holland we can prove with certainty that we must not believe in a supreme height of flood.



House at Willemstad indicating the height of former disastrous floods. The difference in height between the flood in 1775 and that in 1953 is about 4-ft. Both were extremes in their time.

There are sufficient " signs on the wall " in form of flood stones to show that flood records are being broken again and again. The " highest floods ever known " are indicated by these flood stones, but it would be fatal indeed to believe that the 1953 flood, most impressive as it was, will not be followed by still higher ones.

The second belief might be fatal: namely that the houses in which these flood stones are built sink below the land surface. They do, of course, sink, but not apparently more than the land. The banks or dikes sink more because they are heavier. There is reason to accept that all alluvial soils shrink considerably—not only those of Holland but also those of England and Belgium—until a specific weight of about 2 is reached (ult. 2.65).

The house at Willemstad (see illustration) was built in 1600 by Prince Maurits of Orange near a small harbour on good, but alluvial sandy soil, not better and not worse than the average subsoil of the other Zeeland dikes. It might be compared to the soil on which the banks of the Wash have been built. Nothing indicates that the house has subsided more than the whole town of Willemstad, its quays and dikes included.

Owing to these flood stones we know the rate at which records are broken. It appears that flood records are broken every 30 to 40 years *as an average* by a flood which is about 10-in. higher than the previous unprecedented one, also *as an average.*

A third fatal belief would be to take these averages as a basis for our designs for the future. Averages are too small. There should be added a safety factor of, say 2 or 3. This would be but a meagre figure compared with the safety factors we use for other buildings and structures.

There is a fourth fatal belief, the belief in predictions by frequency curves. Fine straight lines may be obtained by putting frequency data against flood heights on semi-logarithmic paper. Extrapolating these lines we see that the 1953 flood has a frequency of 1/500 a year, and a flood which would have been one metre higher would have a frequency of 1/15,000 only. *As an average* such floods would occur once in 500 years and once in 15,000 years, but let us not believe in averages, nor in these figures, for they may lead us to destruction.

The " signs on the wall " speak clearly enough to show this. The unprecedented flood of 1775 (see illustration) was equalled already in 1776. Both were very high surges with a very low frequency of occurrence at the time they happened. Now, in 1954, their frequency is about 1/5, i.e. they occur every five years as an average. In the not too far distant future they will occur once a year.

So, we must believe in subsidence data, the reader may say. But let us not trust subsidence data either. It might be fatal again. Our subsidence data are obtained from gauges built on poles or rocks, and our banks and dikes are not built on these. For a given country there is not one subsidence figure only but as many figures as there are different soils and depths to be found. We must not trust our present inadequate knowledge of subsidence.

One of the most fatal beliefs might be the belief in the exactness of a subsidence figure derived from readings at an Ordnance Datum gauge. Such a gauge is not meant to give a subsidence figure but to give the height of the Ordnance Datum; Newlyn in England, N.A.P. in Holland. If the levels starting from Newlyn were kept wholely correct the readings at the gauges all along the coast of Great Britain would give the subsidence line of Newlyn only, because the aim is to have the exact O.D.N. level everywhere. We engineers need not only O.D. gauges but also local subsidence gauges—several in one vertical to learn the subsidence at different depths.

" Subsidence gauges " may be simple: an iron rod placed on a concrete block at a certain depth, surrounded by a tube, so that the latter may take the friction of the soil. The tube must not rest upon the concrete block.

Let us heed the simple signs on the wall, that we may not read some day " Mene, Mene, tekel." It is a certainty that flood records are being broken at not too great intervals. This is certainly true in Holland. Not only the flood stones tell us this but also the papers in our archives.

Yours faithfully

J. Van Veen,

Rijkswaterstaat,
Holland.

26.2.54.

Port Development at Kotka.

With a view to increasing the capacity of the Port of Kotka, situated on the south coast of Finland, intensive enlarging and improvement work is being carried out. In connection with the extended macadamisation of the quays, the handling of goods has been increasingly mechanised. A new stretch of quay now under construction has a length of about 600-ft. (210 metres) while the depth of water alongside will be 27-ft. A new coal harbour is also planned, and it is estimated that, through the expansion and modernisation now in progress, the capacity of the port will be increased by 1,000,000 tons per annum. During the peak year 1951 no less than 2,500,000 tons, mainly export goods, passed through the port, while in normal years the figure is in the neighbourhood of 1,700,000 tons.

During the latter part of 1953, the figures for traffic in Finland were, in general, lower than last year, chiefly owing to the present high cost of production and the one-sidedness of Finnish exporting industries. As far as sea-borne goods are concerned, a general reduction of some 15-20 per cent. was to be observed, with considerably more in the case of certain kinds of goods.

Salving the "Empress of Canada"

A Port Authority's Great Feat

By Captain H. V. HART, R.N.R. (Ret'd.).

It will be remembered that prominent among the shipping casualties of last year, was that involving the loss by fire of the "Empress of Canada," in the Gladstone Dock, Liverpool.

This vessel, a 20,000 ton liner, formerly the "Duchess of Richmond," and owned by the C.P.R., was lying at her berth in the dock, after completion of a refit, when she suddenly became on fire, and after extensive fire-fighting efforts, listed heavily, and eventually heeled completely over, and sank.

As the result of this casualty, the Dock Authority (Mersey Docks and Harbour Board) became not only deprived of the use of a valuable dock berth for over a year, but also, confronted with the problem of the most formidable dock salvage operation within history in this country, and also with the enormous pecuniary loss occasioned thereby.

The circumstances into the loss of this vessel, as following a number of similar ship fires in ports, have recently formed the subject of a most comprehensive and lengthy Court of Inquiry, instituted by the Ministry of Transport, the findings of which have not yet become promulgated.

The immense operations involved in the salvaging of a vessel of this size became the immediate concern of the Marine Department of the M.D. & H.B., which always maintains one of the largest stocks of every kind of equipment as required for marine salvage purposes, and has recently built and put into commission two new powerful salvage vessels.

The salvage staff, under the able direction of Captain W. R. Colbeck, R.N.R., the Board's Marine Surveyor and Water Bailiff, with whom the responsibility for this salvage operation rests, are among the most experienced in the world, and among several hundreds of every type of salvage operations, have already successfully salvaged a smaller vessel under similar circumstances.

The salving of this vessel, as in the cases of other vessels under similar conditions, involves two separate and different operations. The first, consists of uprighting the vessel to (as nearly as possible) an even keel in the dock, which constitutes the more formidable problem, and demands many months of intensive preparatory work, and enormous expenditure, in providing the equipment and means as necessary in a case of a ship of this size and weight. The second operation is that of preparing and pumping out and refloating the vessel and restoring her to a safe condition for towage (in this case) to a breaking up berth.

The necessary preparations for this latter operation will extend over several weeks, and therefore only the primary and main operation of uprighting the vessel will form the subject of the present article. The only possible alternative means of removal of the vessel to that as decided upon by the Board, was by "cutting up" the vessel as she lay, but this method for several reasons was not admissible. The first step in the present operation was to make the essential inspection of the vessel, with regard to her condition, as the result of the fire, and consider her internal constructional arrangements in connection with the practicability of making use of certain compartment spaces to supply buoyancy, in assisting her uprighting, for which the "haulage" power, and buoyancy as available by outside means, would be insufficient.

Intricate calculations were also necessary to accurately determine the exact amount of power required to upright the vessel, with computed allowances for various factors, including suction exerted in the vessel at the initial "pull"; probable intake of mud, etc.; and other questions relating to the various stages of the operation. All available plans of the vessel were carefully studied, and for better exemplification of which a scale "skeleton" model was constructed and a special office to deal with these and to act as headquarters for the preparatory salvage work was established in the dock shed alongside the vessel.

Fig. 1. Fore and aft view of wreck and tripods.

Fig. 2. Close-up of tripods and 9-in. wires.

The initial practical step in the operations was to remove as much oil fuel as possible from the vessel as this was continuously leaking into the dock and severely hampering all diving operations with the added and serious risk of fire, and this oil was regularly skimmed from the surface of the water and confined in areas by floating booms.

In order to reduce the weight in uprighting, the whole of the vessel's structure above the upper deck was removed by surface burners, cranes and divers and the total amount recovered exceeded 800 tons, of which each funnel weighed 50 tons.

Examination of the vessel showed her to have been severely structurally damaged over a considerable area by the intense heat of the fire. The upper plating in the after end of the vessel was badly buckled and weakened to an extent to preclude the erection of tripods over that section of the vessel. It was also found that a considerable number of plating and other rivets in the structure of the vessel had been loosened and over 6,000 of these were removed and the spaces welded to preevnt leakage which would have seriously impaired salvage operations. All ports and openings on the upper side of the vessel were also effectually sealed by welding.

During the course of these preliminary operations, assessment was made as to the extent of additional plant and equipment to be eventually required and which it would be necessary to collect from various sources throughout the country. This comprised such main items as winches; purchase wires and blocks; pumps; air compressors; pontoons; heavy wires, cut and spliced to required lengths; additional diving equipment; cement foundations of winches; steel for tripods, etc., etc.

The vessel capsized on to her port side (towards the quay) and lay at an approximate angle of 90° with 230-ft. of her length resting on the bottom of the dock.

Her beam of 75-ft., and with the normal depth of 45-ft. —50-ft. of water in the dock, projected about 25-ft. above that level.

It was estimated that during her long submergence the vessel had accumulated some 2,000 tons of mud in her various compartments in semi liquid form.

All the above preparations had been completed several weeks in advance of the date for uprighting, and then the work commenced of attaching the pontoons to the vessel, for the dual purposes of providing buoyancy and leverage on the two sides respectively.

In addition, the heavy 9-in. wires attached to the base of the tripods were extended 450-ft. across the dock and attached to the winch purchases.

Salving the "Empress of Canada"—continued

Fig. 3. Showing 9-in. wire housed inside flanges of vertical bar of tripod.

The recovered buoyancy spaces in the vessel were tested for leakage and the requisite air compressors, portable steam boilers, etc., placed in their positions, together with the multitude of other duties as inseparable from a salvage operation of this magnitude.

The several forces available for the purpose of uprighting were disposed as follow :

Internal Buoyancy.—This was provided by the " sealing " of three separate spaces in the submerged side of the vessel, having a total capacity of 7,600 tons of water. These major spaces were again sub-divided into eight minor spaces, in order to reduce the risk of leakage of the applied compressed air, in any one of the major compartments. These sub-divisions and their respective capacities were: (1) No. 1 hold, 815 tons; (2) No. 2 hold, 825 tons; (3) forward accommodation, 1180 tons; (4) centre accommodation, 1999 tons; (5) upper aft accommodation, 364 tons; (6) No. 6 hold, 662 tons; (7) No. 7 hold, 798 tons; (8) No. 7 hold, 975 tons; total capacity 7619 tons. The water from these spaces was expelled by compressed air operated by 12 air compressors, passing through a major pipeline attached below the edge of the quay, with branches to each buoyancy space.

Exterior buoyancy was provided by the use of 11 pontoons, each of 80 tons capacity and attached with 9-in. wires to the submerged side of the vessel. These pontoons were submerged and "blown" by compressed air and contributed a total of 880 tons lifting power.

Leverage power comprised six pontoons, similar to the above, attached to the upper bilge of the vessel, giving a total righting force of 690 tons.

Tripods.—A total number of 16 20-ft. steel tripods were erected on the upper side of the vessel, each being capable of sustaining a strain of 200 tons. The legs of these tripods were fastened to the upper plating of the vessel and the uprights carried down into interior structural portions of the vessel in order to provide increased rigidity and stability. These uprights consist of heavily flanged bars in which the 9-in. wires are housed and attached to their bases by heavy steel toggles rove through the end splices of the wires.

These 9-in. wires are carried across the dock to within 90-ft. of the winches, at which point they connect with the 3½-in. six-fold purchases. Steam for the winches, etc., is supplied by six portable boilers and six hoppers.

The total buoyancy and leverage forces as applied by the above means for uprighting are therefore as follows:—

	Tons
Internal buoyancy in vessel ...	7,600
External buoyancy as per 11 pontoons	880
Leverage by pontoons	690
Leverage by tripods	1,600
Total forces applied	10,770

This total gives a 40 per cent. margin of safety over the requisite figures as necessary for uprighting.

Fig. 1 shows the inclination of the vessel and line of tripods.

Fig. 2 shows a close-up of the tripods and method of construction.

Fig. 3 illustrates the housing of the 9-in. wires within the flanges of the upright of the tripod.

Fig. 4 shows the leverage pontoons attached to the upper bilge of the vessel and 9-in. wire stretching across the dock.

Fig. 5 is a diagrammatic sketch of the general arrangements and dispositions of forces for uprighting.

For the purpose of continuous and efficient supervision of the operations a compartment has been provided on the first floor of the shed directly overlooking the vessel and connected by private telephone lines to all salient positions, whereby the official-in-charge can control all the various stages of operations and exercise instant control over the same.

March 6th had been chosen as the date on which the operation would commence, as being the earliest by which all preparations would be completed, and also as that on which to coincide with one of the highest spring tides of the year. This latter was desirable both for the purpose of reducing the weight of the vessel and providing the greatest possible range of buoyancy effort.

The preliminary operation of the application of compressed air to the buoyancy spacer in the vessel, and to the submerged pontoons commenced in the early hours of the 6th, and during the forenoon all purchases on the 9-in. tripod wires were hove taut and " synchronised " for even pulling power on the winches. At 12.27 p.m. the spring tide had reached its highest level of 31-ft. 7-in., and the level of the dock water had been further raised by impounding from the system.

The 12-in. clinometer on the bow of the vessel showed an inclination of 87°, and at 12.38 when the power was first applied, the initial moment of inertia was immediately overcome, and the vessel slowly and steadily began to rise, and at 12.48 p.m. the inclination had decreased to 45°. At this point it became observable that during the course of uprighting the vessel had also slid towards the centre of the dock, and notably at the forward end. The forward tripod purchases were therefore discontinued, but as the bodily movement of the vessel continued, a pause in the operations became necessary, in order to overhaul the purchases for further exertion of pulling power.

At this stage, the vessel had reached her position of " balance," and the previously submerged pontoons on the under water side were floating, and thereafter ceasing to exert further influence on uprighting, and great eruptions of water became continuously expelled from the interior of the vessel, by the compressed air. At 1.20 p.m. after the readjustment of purchases, and under the strain of a single tripod wire, and the assistance of the internal buoyancy, the vessel again began to upright, and in a few seconds, had moved to 18 degrees of list.

At 1.22 p.m. the vessel assumed her final inclination of 9°, and the tripods became submerged in the water.

Under however the influence of internal buoyancy, and the gradual pressure exerted on the mud under the bilge, the above inclination is likely to be further reduced, during the resulting 24 hours.

In this immense salvage operation, all preliminary calculations have proved to be of perfect accuracy, and all the necessary preparations extending over 14 months, as carried out to preconceived plans, have correctly fulfilled all anticipations, and the entire operation completed with the utmost rapidity and exactitude.

The operation was watched from the roof of the adjoining warehouse, and from the quays, by a large attendance of persons,

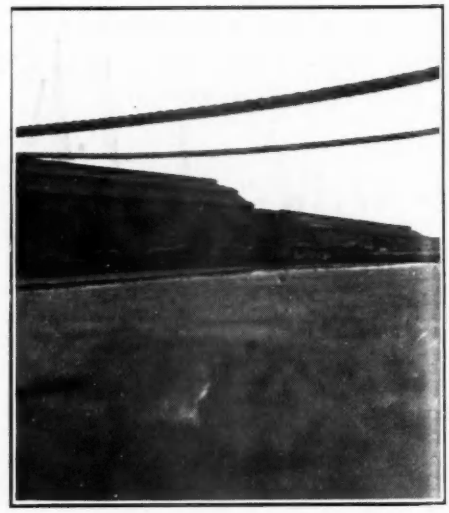


Fig. 4. Pontoons attached to upper bilge of wreck, and 9-in. wires across dock.

Salving the "Empress of Canada"—continued

including representatives of salvage associations, from both the U.K. and other countries.

This operation concluded the first, and most difficult stage in the salvage of this large liner, which has constituted the biggest problem of dock salvage ever attempted in this country and demanded major efforts of skill and work on the part of those faced with the responsibility of this formidable task.

For the entirely successful conclusion of this operation, the greatest credit, and heartiest congratulations must be accorded to Captain Colbeck, and all his able staff, who have achieved this great feat of salvage.

The Second Operation of Salvage.

In a few weeks time the vessel will have been prepared for the second operation of salvage, i.e. refloating. Before this takes place, a great amount of work becomes necessary. All ports and other openings in the hull which were on the submerged side of the vessel will require to be sealed and efforts will be directed towards the removal of great quantities of mud, which have accumulated during the vessel's submergence in order to avoid her taking a serious list when refloating previous to the removal of the major quantity of "loose water" in her, of which, it is estimated, some 12,000 tons must be pumped out.

It is also essential that at the moment of first refloating the vessel does so in (as nearly as possible) her own draft of water in her then condition, as under these circumstances a vessel almost invariably develops a certain amount of list which is then checked by her thereby increased draft as the bilge takes the bottom.

For this reason the dock will be run down to a level of her estimated draft and all main and secondary pumps will be placed in their respective positions and connected up to their suction pipes as previously installed. During the approximate three hours interval available some 12,000 tons of water will be removed from the vessel by twelve 12-in. pumps each having a pumping capacity of nearly 1,000 tons per hour. As soon as the main pumping has been completed the numerous small pumps will be employed in the removal of water from the various "pockets" in the vessel and in clearance of the numerous small compartments and spaces. The main pumping should reach completion in shortly over one hour and by the time of return of tide the vessel should be clear of all loose water and refloating. The question of ballasting will arise, and if needed as by previous calculations, this will be provided either by the utilisation of the vessel's tanks or by external means. If doubt exists as to her stability when refloated this will be augmented by the use of pontoons and/or camels attached to each side of the vessel.

When finally afloat and in a safe condition, the vessel will be placed in graving dock for preparation for her final removal to a breaking up yard.

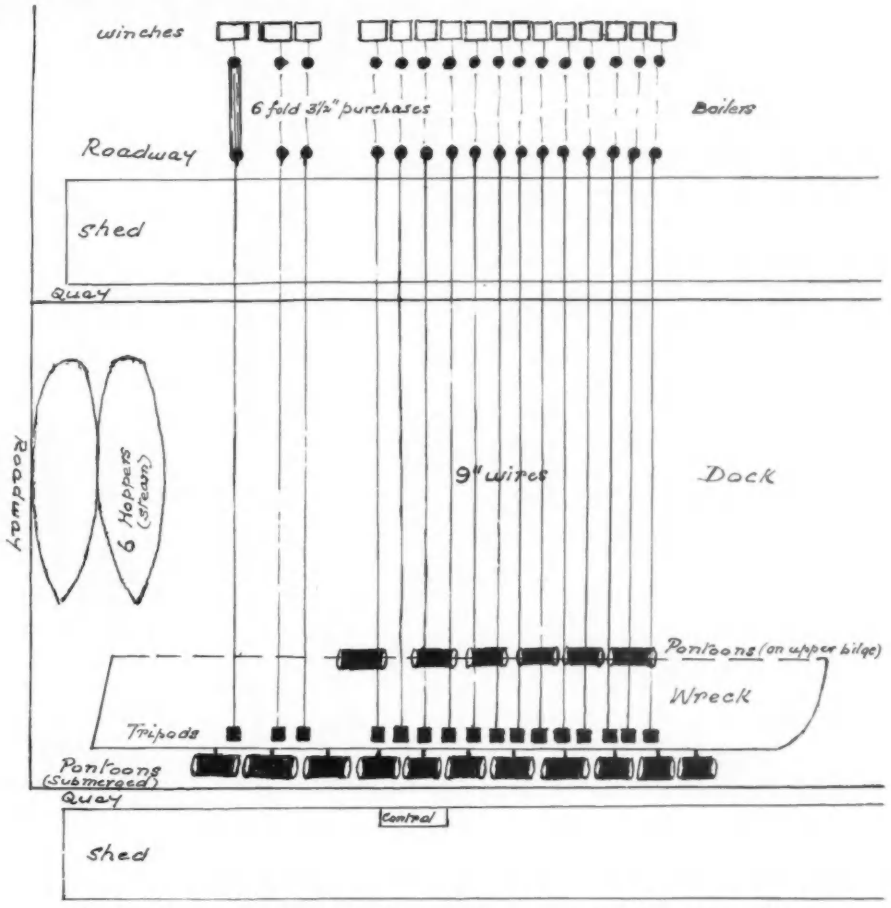


Fig. 5. Diagrammatic sketch showing general arrangement of forces for uprighting.

Report of Committee of Enquiry

The findings of the Ministry of Transport Court of Enquiry into the loss by fire of the *Empress of Canada* have now been published. The Court found that clandestine smoking was the most likely cause. The most probable explanation was that a cigarette end had been discarded in a cabin. Pointing out that the seriousness of fire risk on board a vessel in the situation of the liner was not fully appreciated, the Court stressed as most urgent the recognition that any vessel out of commission and under repair is a completely different problem from such a vessel in full commission.

The Court sat for 18 days in December and January, under the chairmanship of Mr. Carpmael, Q.C., Commissioner of Wrecks.

The Court's report states that several unsatisfactory features in regard to fire prevention and fire fighting in ships in port emerged during the enquiry, and lists the following points in regard to the *Empress of Canada*: No liaison existed between the owners and the fire brigade; fire patrol frequency was below the recommended standard; clock patrols operated only at night, and at the time of the disaster personal alarms, such as whistles, were not supplied; a direct telephone line from ship to fire brigade was not available; the fire main was uncharged and no alternatives had been instituted; fire doors and water-tight doors were not closed; and gas cylinders were not as wisely disposed as possible.

It was clear, says the report, that smoking was carried on to a considerable extent on board the ship. In view of the difficulty of this question, particularly the danger of driving the practice "underground," which in itself might increase the fire risk, the report urges "judicious propaganda and support from trade union representatives."

The possibility of incendiarism is mentioned, but is dismissed "in the absence of any clues," but the Report criticises the sweeping away of the debris, on the starboard side of the ship before it had been investigated, "thus removing all the evidence."

With regard to the precautionary arrangements taken against the possibility of fire, the treatment of this important matter by the chief officer and the assistant chief engineer "appears to have been casual in the extreme. The chief officer appears to have accepted the position that there was no water instantly available, while the assistant chief engineer did not make certain that all his junior officers were informed of what was to be done in an emergency." In the result, there was no water in the fire mains either on the Saturday or the Sunday.

Liverpool Observatory and Tidal Institute

Research on North Sea Storm Surges

The Annual Report of the Liverpool Observatory and Tidal Institute for the year 1953, deals with the routine work of tidal predictions, the supply of which to almanacs and private publishers is on the increase, and with the other activities which the public have come to associate with this Institute. Supporters of modern electronic methods will be interested in the Director's statement that tidal predictions would not be performed any better by high speed computors than by the use of the existing machines, while the results would be four or five times more costly.

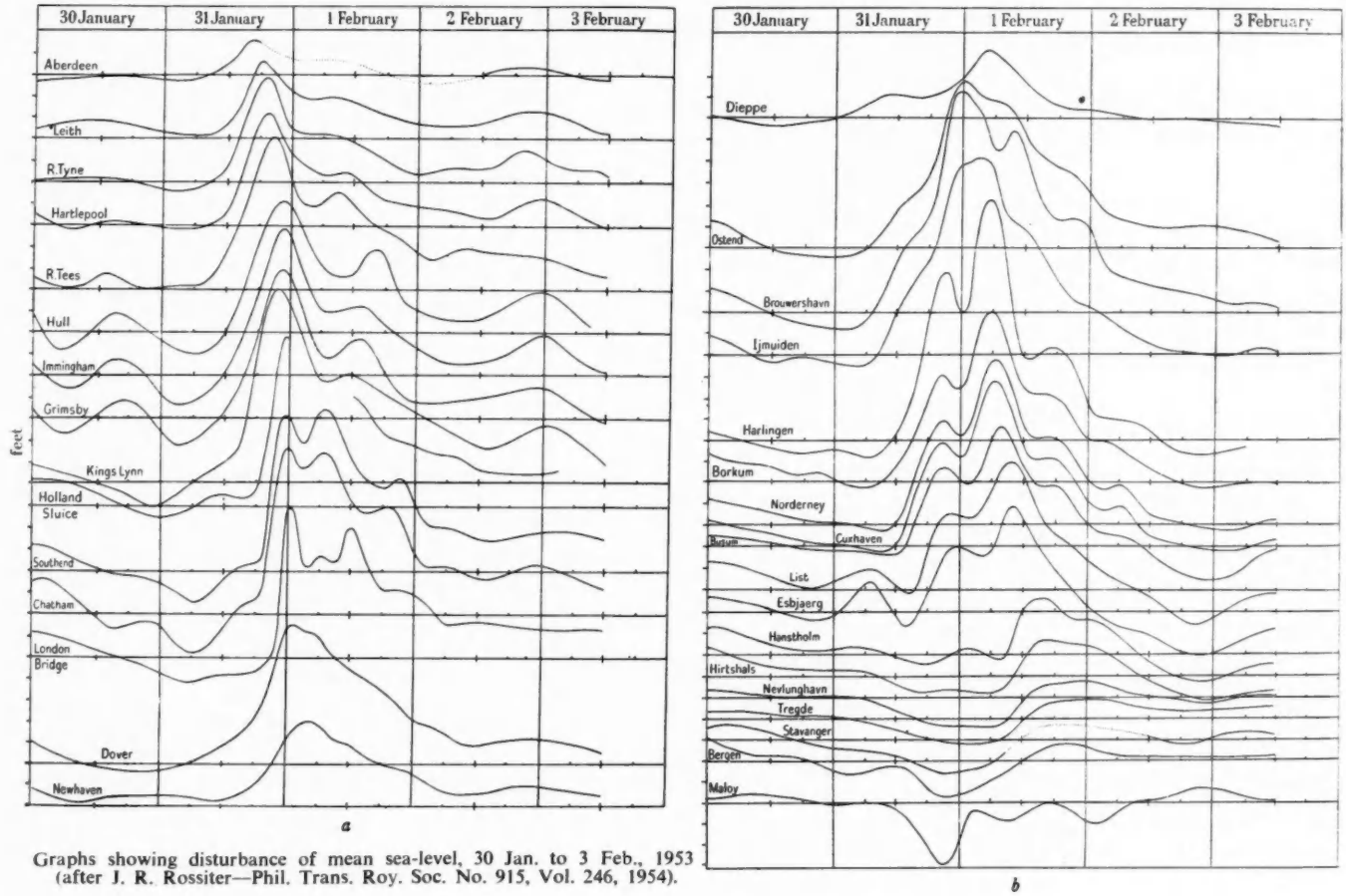
In the section on meteorological instruments, it is noted that the sunshine recording sphere was tested at the Meteorological Office and found to be defective, passing appreciably less sunshine than the standard instrument. The discrepancy amounts to about 4 per cent., and an investigation has revealed that the totals for recorded sunshine have been deficient since about 1915. A method of correcting the long period mean, with which the Meteorological Office agreed, has been devised. (It would seem to be a matter of concern to all Port Authorities who operate meteorological instruments to check the accuracy of an instrument which, to the laymen, appears from its nature and construction to be entirely reliable.)

After the death of Dr. Corkan the Director was asked to become secretary of a committee on Mean Sea Level, which operates for the International Association of Physical Oceanography (International Union for Geodesy and Geophysics). The principal work of the committee in the past has been the compilation of monthly and annual mean values of sea level for the whole of the oceans and seas. There have already appeared two publications of the data which have been collected for the Association by the International Hydrographic Bureau, and which have been reduced, for the first volume by Professor Proudman, and for the second one by Dr. Corkan, with the aid of the staff of the Tidal Institute. Mr. Rossiter has been responsible, with Mrs. Corkan, for taking up the work as left by Dr. Corkan, and the third publication, covering a period of five years (and also including previously unpublished data), will be submitted to the Association at Rome next September. Publications of this kind are of the utmost value, and very many people are taking a keen interest in the variations of mean sea level, caused in some instances by sinking of the land and generally by increase of water content of the oceans by the progressive melting of polar ice.

Storm-Surges.

The research activities of the Tidal Institute have been greatly affected by the phenomenal storm-surge which caused devastation and loss of life in South-East England and in Holland. Research concerning storm-surges has been a prominent feature of the work of the Tidal Institute from its inception in 1919, and the pioneer work done by Prof. Proudman and Dr. Doodson in the years prior to 1928, when a surge caused much loss of life in London, enabled Dr. Doodson to investigate the causes of that surge. From that time onwards he and Dr. Corkan worked together and some portion of their work has been published. The methods used by Dr. Corkan for computing the effects of meteorological changes in sea level gave very accurate results in nearly all the cases studied.* The surge that occurred at the end of January differed in some respects from others previously experienced, partly on account of its magnitude and partly on account of factors which had not previously been of importance. But if the formula given by Dr. Corkan had been used when the meterological situation was threatening it would have sufficed to have indicated the magnitude and time of maximum of the surge. Too much emphasis cannot

*Readers will recall that an article on this subject by the late Dr. Corkan appeared in the February 1948 issue of this Journal.—Ed.



Graphs showing disturbance of mean sea-level, 30 Jan. to 3 Feb., 1953 (after J. R. Rossiter—Phil. Trans. Roy. Soc. No. 915, Vol. 246, 1954).

Liverpool Observatory and Tidal Institute—continued

be laid on the necessity for quantitive estimations of the highest possible accuracy, for surges are disastrous by reason of the close time relation between the maximum of the surge and high water. Very large surges have been experienced in many parts of the country but they have not caused loss of life or material damage because they have occurred on neap tides or at low water. Forecasters have very little time for very elaborate calculations so that the formulae that have been put forward have been simplified more than is strictly desirable, but formulae for practical use cannot be expected to be as accurate as those which may be used by a research worker. There is no question, however, that a calculation of effects as indicated by the meteorological forecast of winds, combined with reports of tidal observations from along the coasts, can be effective in giving due warning.

When the surge occurred, the Institute was immediately asked to co-operate. Special tidal predictions were computed for the dangerous periods for use by the tide-watchers, and observations were collected for an investigation of causes. All this work fell on to Mr. J. R. Rossiter owing to the illness of the Director at that time and for most of the year. His investigations have been made on lines similar to those pursued by Dr. Corkan in a paper dealing with a particular storm, and the tidal observations round the coasts of the North Sea have been reduced so as to show the storm-surge which was superposed on the tidal oscillation. The results have been combined so as to give some idea of the flow of water into and around the sea. Of course it is impossible to give exact pictures of what took place in the open sea but the contour lines which have been drawn have been tested by certain dynamical theories and can be considered as showing the character of the surge more than a curve or series of curves for places along the coasts only. The drawings have been made at intervals of three hours over the period of the surge.

The term " surge " was introduced by the Director to emphasise that the disturbances of sea level by wind were dynamic effects as distinct from a slow increase of level to a fairly steady condition lasting for one or more days. In the case under consideration there was a mixture of effects, for the sea-level remained quite high for over a whole day with surge peaks superimposed upon it. The whole of the Flemish Bight (from South-east England eastward) suffered a large rise of level upon which were surges which travelled along the coasts.

The full results of the investigation are given in the Transactions of the Royal Society, Series A, No. 915, Vol. 246, pp. 371-400. Reports were also made to the Waverley Committee which was appointed by the Government to investigate the surge and its effects.

Very many requests have been made from many parts of the country for information bearing upon local problems, but all these must await further research covering all the coasts of Great Britain. The problems are complex and will take much time for their solution, and little needs to be said as to the costs of such investigations.

The Director has undertaken to lead a symposium on the subject of storm surges at the next meeting of the International Union of Geodesy and Geophysics in Rome next September.

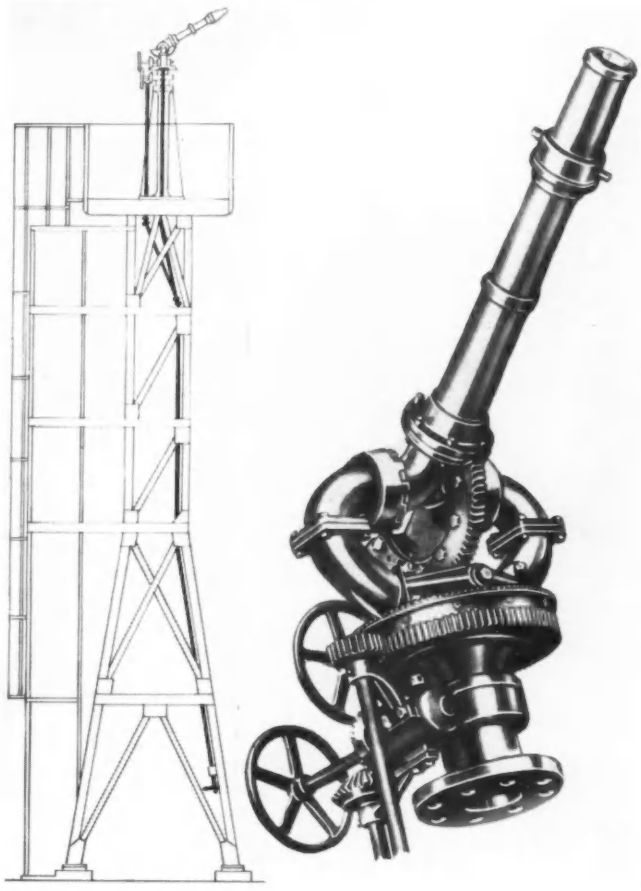
Fire Prevention at Ports and Oil Terminals

Jetty Monitors Afford Efficient Protection

By J. D. SHAPLAND, B.Sc., A.C.G.I.

A remarkable expansion of the oil industry in the last few years has resulted in the erected of refineries, oil storage depots and bulk terminals along the coast in different parts of the world, generally in or adjacent to harbours and ports. This development coupled with the increase in use of fuel oil in ships to provide the motive power, has created a fire problem which is confronting Port Authorities with a serious situation. The old methods of fire fighting, using water for extinguishment, are no longer efficacious and new ways of fighting ship fires must be found.

Reports are continually appearing in the Press of fire and explosion on oil carrying ships and barges, with heavy loss, not only of property, but often of human lives. Such fires sometimes occur at sea, where the ship is entirely dependent upon its own fire fighting resources, but more often when a vessel is moored to a quay or jetty and is loading or unloading inflammable liquids. A particularly dangerous time being when tanks are empty and the remaining oil vapours are released at the manhole openings during the steaming and gas freeing of the tanks.



All photographs by courtesy of Foamite, Ltd.

Fig. 1 (left) Diagrammatic arrangement of a Jetty Tower. Fig. 2 (right) Close-up view of the Monitor.

For this reason, the oil jetties of the most modern refineries are being equipped throughout their length with fire fighting towers situated at strategic intervals. These towers each carry a Monitor capable of discharging a powerful jet of foam on to a burning vessel. Where such protection is installed, the foam monitors may be trained on the vessel as soon as it is moored alongside, so that no time is lost in directing the foam jet, should a fire break out.

The monitor designed for this particular application is suitable not only for foam but also for water. The elevation and rotation may be achieved either at the monitor itself or from ground level at the base of the tower as it is fitted with an ingenious gearing arrangement with extension spindles strapped to the tower, allowing for operation from the ground. Fig. 1 shows a diagrammatic arrangement of a jetty tower, clearly showing the position of the monitor with the extension spindles and hand wheels. The monitor itself is shown in Fig. 2. This is of 4-in. nominal size and is manufactured throughout of gunmetal. In order to reduce the frictional losses of the foam or water flowing through the monitor, the shoulders are bowed to give the least resistance to the flow of the liquids. The gearing is carried by twin ball races so as to reduce the friction impeding the rotation and elevation

A single 4-in. feed pipe leading from the ground to the monitor base is all that is necessary for supplying the foam or water. This pipe may be fitted with a tee and control valves at the base of

Fire Prevention at Ports and Oil Terminals—continued

the monitor tower, one side being connected directly to the water supply and the other to a foam making unit or pressure foam maker.

The pressure foam maker, shown in Fig. 3, is in two parts, the proportioner designed to mix water and airfoam liquid (the foam stabilising liquid) in the required proportions and the aspirator to aerate them in order to produce foam under pressure for discharge from the monitor.

Airfoam liquid may be supplied from a truck by pumping the liquid into a supply line from some safe distance away from the jetty tower, or alternatively it may be supplied from a stationary tank of airfoam liquid situated in the pump house in any convenient position adjacent to the jetty. It is unnecessary to supply a pressure foam maker with airfoam liquid under very great pressure, as the proportioner itself inducts the liquid by vacuum. Aspiration of air by the foam solution takes place automatically and the foam is formed throughout its passage up the length of 4-in. pipe to the monitor. The pressure foam maker produces 1,500 g.p.m. of fine quality foam which may be thrown up to 150-ft. or more dependent upon its water pressure.

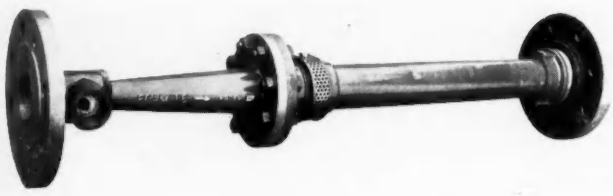


Fig. 3. The pressure foam maker.

An example of the type of truck used to supply a jetty monitor pressure foam system with airfoam liquid is shown in Fig. 4. This consists of a 1,000-gallon tank of airfoam liquid mounted on a Fordson Thames Sussex chassis, the airfoam liquid being pumped under low pressure into the supply line running down the jetty to the pressure foam maker. The positive displacement pump operates from the truck engine through a gear box mounted power take-off, suitable for pumping a large volume at the relatively low pressure required to feed the pressure foam maker.

The alternative method of feeding the pressure foam maker is to incorporate in a foam house a tank of airfoam liquid of adequate capacity, the liquid being proportioned into the water stream at the pump, so that solution, i.e. water and airfoam liquid, is conveyed to the base of the monitor tower, where the air is aspirated at the foam maker, producing foam under pressure.

Fig. 4. A typical fire fighting tender.

When there is a possibility that a burning vessel may endanger nearby shipping, it is frequently the case that it is towed from the jetty into the open sea. Under such circumstances, the fires are usually fought by means of fire floats or tugs capable of throwing a number of monitor jets of water simultaneously. In few cases however, are those floats equipped with adequate foam fire fighting equipment, and the incorporation of pressure foam makers into existing monitors or the mounting of smaller monitors will quickly increase their effectiveness.

Welded Tubular Steel Structures

Recent Examples of New Technique

(By a Special Correspondent)

During the past few years, one of the most remarkable features of fabricated steelwork technique has been the development of welding. A saving in weight of steel is only one of several advantages gained even when the usual rolled steel sections are used in steelwork structures. A further and more recent development has been the application of steel tubes to structural works, resulting in further benefits.

An all-welded tubular steel frame factory—believed to be the first to be wholly fabricated on the site and the second largest to be all-welded—is nearing completion at Kirkby, near Liverpool.

The factory is itself a demonstration of the use of welded tubular steel for construction purposes.

The floor area required for the main production shop was approximately 130,000 sq. ft. with an additional bay for the receipt of incoming materials 60-ft. wide x 185-ft. long to provide 11,000 sq. ft.

The various stages of production and methods of handling the material required large areas of floor space (Fig. 1) unobstructed by internal columns and that the roof structure should be capable of carrying conveyors and welding plant. The other essential requirements being a good intensity of daylight throughout the shop and that it should be heated to a temperature of 55° F.

The main shop is 360-ft. long x 360-ft. wide x 17-ft. high to eaves consisting of six intermediate bays 40-ft. span, and two outside bays 60-ft. span, one of which is extended to form the receiving bay.

The 40-ft. span roof trusses are of the butterfly type glazed on both slopes while the two 60-ft. span outer bays have flat pitched trusses with glazing at the apex. The roof trusses are carried by latticed girders 120-ft. span with columns at 120-ft. x 60-ft. or 40-ft. centres according to the width of the bays.

The roof is covered with aluminium decking with insulation board and two layers of felt and the sides of the building are clad with asbestos protected metal sheeting.

The superstructure is entirely of welded tubular construction except for the glazing purlins which are rolled angle sections (Fig. 2). All joints throughout the structure are welded, the only bolts used being those for anchoring the columns to the foundations.

An unusual feature of the structure is that the individual tubes were delivered to the site in approximate lengths and the whole of the fabrication, including shaping and welding of the tubes, was carried out on the site. It is believed that this is the first occasion on which a tubular building structure has ever been fabricated in this way.

The total weight of steel used in the finished structure was 415 tons, equivalent to 6½ lbs. of steel per sq. ft. of floor area. This weight is estimated to be 40 per cent. less than a similar design using riveted or bolted rolled steel sections. The low steel content of the structure is emphasised by the fact that the allowance for loads carried by the roof structure to provide for conveyors and plant was equivalent to a load of 20 lbs. per sq. ft. of floor area or an increase of nearly 100 per cent. over the normal dead and live load requirements.

The weight of the main tubular columns which are 16-in. dia. is approximately 1 ton each, the 120-ft. span lattice girders weigh 6½ tons each, the 40-ft. and 60-ft. span trusses weigh 8 cwts. and 12 cwts. respectively. The individual lattice girders and roof trusses were fabricated on stillages and the whole of the structure erected by means of two mobile cranes. The whole of the work, including fabrication on site, erection and final welding up of the structure was carried out in a period of 4½ months, by a labour force of 30 men. Six men were employed on preparation of

Welded Tubular Steel Structures—continued

material, 10 on fabrication and the rest on erection.

The architects for the factory, which was built for Tubewrights, Ltd. (a subsidiary of Stewarts & Lloyds Ltd.), were Sir Alfred Shennan and Partners, North House, 17, North John Street, Liverpool 2, and the Consulting Engineer was Mr. T. Bedford, M.I.C.E., M.I.Mech.E., M.I.Struct.E., of 41, New Bond Street, London, W.1. The main contractors were Taylor Woodrow Construction, Ltd., Southall, Middlesex.

Another factory of similar tubular construction has just been built at Hemel Hempstead for Rotax, Ltd.

The main production shop is 460-ft. wide in seven bays 60-ft. span and one bay 40-ft. span, each bay being 360-ft. long, providing a floor area of approximately 165,000 sq. ft.

The tubular columns are spaced at 60-ft. x 40-ft. to suit production requirements. The roof trusses carrying the glazed monitors are 60-ft. span spaced at 13-ft. 4-in. centres, the intermediate trusses being carried on cross girders 40-ft. span between columns. The depth of the trusses is 5-ft. and the height from floor to the bottom chord of the trusses is 16-ft.

The conception of the particular form of structure arose in the first place from the architect's desire for a roof with monitor type north light glazing and to meet this requirement the Consulting Engineer prepared designs for various forms of construction.

It was apparent that the tubular all-welded structure showed considerable advantages. The absence of gusset plates and bolts, the symmetry and lightness of the tubular sections and the delicate proportions of the trusses generally, produced a pleasing lightweight appearance. The painting and maintenance of the structure is minimised due to the smaller surface area of tubes and the absence of ledges and inaccessible surfaces inherent in trusses formed of rolled angular sections.

The most important advantage was, however, the saving in the amount of steel used, the tubular structure being 30 per cent. less in weight than the design using rolled angle sections riveted or bolted together. There was also an estimated saving of 10 per cent. in the cost of the tubular structure which was fabricated and erected by Messrs. Tubewrights, Ltd.

The total weight of steelwork in the superstructure amounted to 460 tons, equivalent to 6.25 lbs. per sq. ft. of floor area. The 60-ft. roof girders weigh 1 ton each including the monitor frames and the 40-ft. girders weigh 16 cwts. each.

A breakdown of the total weight is as follows:—

	Tons
Roof trusses and monitor frames ...	205
Roof girders	64
Columns	39
Purlins	147
Bracing	5
	460

The structure was designed for a superimposed roof loading of 20 lbs. per sq. ft. on the main decking and 15 lbs. per sq. ft. on the monitor frames. In addition, allowance had to be made for carrying four half-ton loads suspended from the panel points of each 60-ft. truss which is equivalent to an additional superimposed load of 5½ lbs. per sq. ft. of roof area.

The time for executing the work also compared very favourably with other types of construction. The building schedule allowed for the erection of one bay a fortnight, i.e. 16 weeks for the whole structure.

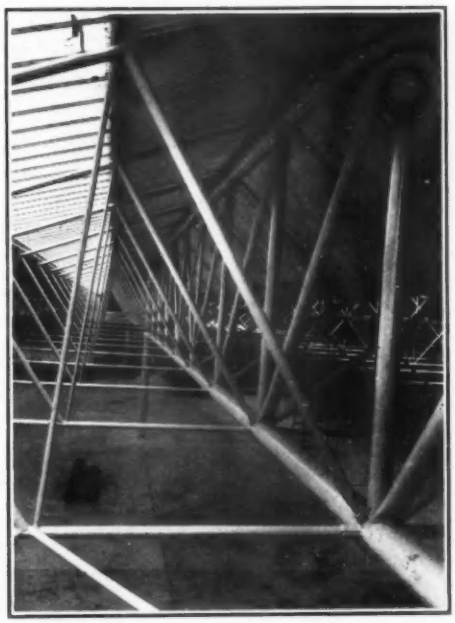


Fig. 2. Close up of the welded roof joints.

The steelwork is a completely welded structure being, in this instance, prefabricated at works as far as possible, the trusses and girders being delivered by road in complete units. No bolts were used, even for erection purposes, with the exception of foundation anchor bolts.

The erection of the structure was a simple operation facilitated by the welding of semi-circular cleats to the columns which provided self-aligning seatings for the trusses and girders and also, with the addition of a similar top cleat, formed the permanent connection.

Other applications of the welded tubular construction include light bridges, examples of which have been supplied, among other users, to the Southampton Harbour Board and the Port of London Authority.

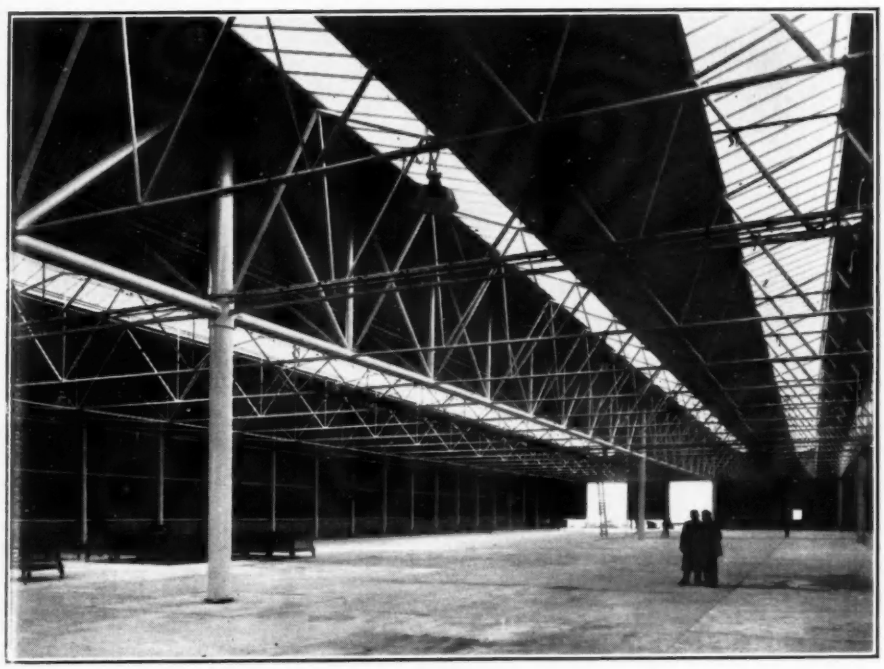


Fig. 1. View of completed building at Kirkby, near Liverpool. Note unobstructed floor space.

Mexican Port Development

It was recently announced that the Mexican Government has awarded a contract for the construction of warehouses, breakwaters and railway yards at the undeveloped port of Guaymas. Situated at the northern section of the Gulf of California, this port is only 260 miles from the U.S. border and is linked in the United States by rail and road, so that when the port is completed, shipments from the eastern areas of the United States will move through the Panama Canal by ship rather than over land by train or lorry. In addition to the construction works mentioned above, the harbour will be dredged from 22-ft. to 32-ft. depth. Two large hills facing the bay will also be removed in order to level the ground for the warehouses.

Damage to Goods in Loading Ship

Need for Legal Definitions of Responsibility*

By a Barrister-at-Law.

An interesting problem arose recently as a result of a mishap which occurred during the loading of a ship. It points to an exception to the rule that simplicity in agreements is the surest way to avoid complicated lawsuits. It serves as a reminder that, when passing goods into the hands of others, it is always advisable to know, from the start, on exactly what conditions they are accepted, not to wait until a claim for damages has arisen before finding out who can be made responsible.

Common carriers of goods are bound, by law, to undertake certain responsibilities and liabilities—they cannot make conditions to exclude liability for damage caused by their own negligence. Others who handle goods are not so bound. Owners of goods may find their claims barred by conditions of handling and carriage which were never effectively brought to their notice.

A small manufacturer of metal shop fittings whose principal business was in this country obtained a comparatively large order abroad. He arranged with a shipping agent for the export of the goods. These were packed in a dozen crates, one of which was unfortunately dropped in loading and fell several feet on to the deck of the ship, apparently owing to a fault on the part of the craneman; the contents were damaged, and had to be replaced in a hurry at some expense. As the export order was out of the usual run of business and there was a special finish to the metal for tropical climates, the expense of replacing extended beyond the normal cost of the goods and the packing of another crate, and included the rushed supply of further fittings with the same finish.

Where there is negligence like this and the shipowner is responsible for the loading and unloading, in charge of the goods from the wharf until discharge from his tackle at the port of destination, he is liable for the acts of his crew and those working under his direction because he is not allowed by the Carriage of Goods by Sea Act to contract out of liability. In this case, however, the shipping agent had arranged the loading himself, and as shipping agents are not common carriers the terms on which they handle goods depend solely upon the contract they make with the owners of goods. The question therefore arose whether the shipping agent was liable for the damage, for it was clearly the fault of those for whom he was responsible which had caused the damage.

The shipping agent was himself apparently under the impression that he had contracted without liability for negligence, for when the manufacturer put forward a claim he refused to meet it, and when asked to give his reason, stated that he accepted goods " on the terms contained in the relative Bill of Lading," a document issued by a third party, the shipowner.

The manufacturer then began to consider (for the first time!) who was responsible under these terms, and discovered that the position was by no means clear. The Bill of Lading merely stated that the shipowner was not responsible for his own negligence if goods were damaged " before they passed the ship's rail for loading" (the shipowner cannot, it will be remembered, exclude liability after this point), and said nothing, naturally, about the position of the goods before they came into his charge.

The position therefore offered a number of possible interpretations. The shipping agent might hold the goods under a liability similar to that of the shipowner, so that he would be liable for negligence while the goods were in his care but not otherwise, or he might on the other hand be liable with the shipowner after the goods had passed the ship's rail but not before.

Again, the shipping agent might be liable for the goods on the terms of the Bill of Lading as long as they were in the shipowner's charge, and be subject to the conditions implied by custom for shipping agents at other times, or a fourth possibility is that the Bill of Lading terms might be applied to the time the goods were in the custody of the shipping agent as far as they could be literally applied to the different circumstances, and the shipping agent would then again be liable for negligence.

A careful consideration of the possibilities shows that in only the second of the four cases mentioned does the shipping agent escape liability.

Two further points in law favoured the manufacturer's claim: in the first place, it is a rule of law that in cases of ambiguity a document is always construed against the person responsible for its production; the second is that in cases where a man wishes to escape responsibility for his own negligence he must say so clearly. On this basis alone, therefore, a consideration of the position seemed to pronounce decidedly in favour of the manufacturer's claim.

One further point of interest arose in the case: the construction of the expression " within the ship's rail." Quite a logical, precise and compact expression when it relates to goods in a stable position, for obviously if goods are stowed anywhere, even on deck, the master is responsible for them. But what about goods swinging in the air from a crane? Is the shipowner responsible for damage which occurs when goods are dropped from a crane and hit the deck but not if they fall into the sea, because they were not then vertically " within the ship's rail"? Or do the words mean " safely stowed on deck"? If they do, why not say so? It is strange that the expression does not seem to have been interpreted by the courts.

With all these doubts it is not surprising that the shipping agent sought to repudiate liability for the damage, even although the scales seemed weighted against him. Luckily, however, the amount involved in the dropped crate was too small to warrant the expense of a lawsuit, and the matter was eventually settled without going to court, but if a larger sum had been at stake it might well have meant a little less willingness on both sides to concede points, and a long hearing before a court.

The important thing about the matter was that the position was not clear from the start, and the manufacturer had to go into the law very carefully and fully in order to ascertain his position *after he had suffered the loss*. Before goods are entrusted to others a short inquiry should always be made on who is to bear the risk for negligence. Common carriers must do so, but with other handlers of goods there is always a risk of disputes over claims if the position is not clear from the start.

* Reprinted from the January, 1954, issue of *Transport Management*, by the kind permission of the Institute of Traffic Administration.

New Passenger Terminal at Liverpool

A commodious new terminal for passengers travelling by the British and Irish Steam Packet Co., Ltd., was officially opened early this month at East Princes's Dock, Liverpool. This four-storied building which was constructed at a cost of £75,000 represented the completion of an enterprising, four-year project. Up to three years ago the B. and I. boats docked at the Liverpool landing stage. At the request of the Shipping Company, however, the Mersey Dock and Harbour Board constructed the new Waterloo lock, which enabled the Dublin boats to dock at East Princes's Dock, no matter what the state of the tide. The original passenger facilities were poor, but the new terminal building will provide the most modern service in Liverpool.

The new building has been carefully designed. A long, roofed-in promenade leads from the road to the central block, where are provided every amenities for both third-class and first-class passengers. The third-class passengers have a booking office, waiting room and refreshment buffet on the ground floor. On the same floor is also the Customs' examination room. From this the passengers walk straight on to the boat.

The first-class passengers have similar facilities on the first floor. In addition to the staircase there is a lift and a conveyor belt for luggage up to the Customs' examination room. After the Customs examination the passengers can walk along a covered passage to the ship; their luggage is taken by conveyor belt. The remaining two floors are devoted to staff restaurant and administrative offices.

Modernisation of Jubilee Bridge, Barrow-in-Furness

New Operating Equipment and Control System

Introduction.

The Jubilee Bridge (Fig. 1) which spans the Walney Channel between Walney Island and the mainland at Barrow, was recently reopened after modernisation of the operating equipment associated with the double bascule opening span. All the electrical drives and cabling have been replaced, and a new control system embodying the Ward Leonard principle has been designed to enable the complete sequence of operations necessary when raising or lowering the bridge to be fully automatic and under the control of a single handwheel.

The bridge was first opened in 1908, the growth of the Barrow shipyards having necessitated the building of houses on Walney Island until traffic across the channel increased to a volume far exceeding the capacity of the existing steam ferry service. For many years it was necessary to make portage charges for use of the bridge, but in 1935, the Jubilee Year of King George V, it was freed of tolls and given its present name.

Structure and Principle of Operation.

The total length of the bridge is more than 1,100-ft. comprising eight fixed spans, ranging from 82-ft. 8-in. to 117-ft. 10-in. clear, and an opening span of 120-ft. which, when closed, gives a clear headway of 18-ft. above high water. The two leaves of this opening span operate on the Scherzer rolling lift system, the principle of which is shown in the simplified drawing of the rear portion of one leaf (Fig. 2).

It will be seen that the rear part of each side of the leaf is formed as a segmental girder which rolls on a longitudinal track, rectangular holes being milled in the curved plate covering each segment to correspond with projections on the track plate. The main driving motor, mounted inside the leaf, is coupled through gearing to a driving shaft carrying two pinions, one on each side of the leaf. Each pinion engages a longitudinal rack rigidly supported on a framework attached to the piers of the bridge. When the motor is energised and the shaft rotates, the thrust of the pinions against the teeth of the racks is sufficient to cause the segments to roll along the tracks, thus tilting the leaf in a manner similar to the action of a rocking chair.

The raising operation carries the whole leaf back from the opening of the bridge and, as a result, a tilt of less than 75° is required to give a clearance through the opening which, in the case of an ordinary bascule bridge, would necessitate raising the leaves through an angle of 90°. In addition, by the provision of balance weights, the centre of gravity of the leaf is located at the rear of the bridge seat, thus reducing to a minimum the power necessary to raise and lower the bridge.

When the bridge is in the fully closed position, the rear end of each leaf enters an inverted stirrup formed upon an extension to the adjacent fixed span. In order to lock the leaf in this position and to prevent it from deflecting under passing loads, two powerful eccentric locking pawls are provided, the shaft actuating the pawls being driven, through worm gearing, by a small motor attached to the fixed span. Fig. 3 shows the rear end of the Barrow leaf.

The front ends of the leaves are designed to close with an interlocking action so as to prevent hammering due to passing loads.

Electrical Drives.

Each leaf is powered by a 25 h.p. D.C. motor (Fig. 4), having a maximum speed of 400 r.p.m. The machines are of totally enclosed construction and are mounted inside the leaves, the armature of each motor being supplied, through flexible cable, from its own Ward Leonard motor generator set which is installed in a control cabin adjacent to the rear end of the leaf concerned (seen in the view of the Barrow control cabin, Fig. 5). A standby motor is also provided on each leaf and may be connected in circuit by means of a change-over switch incorporated in the control gear. A powerful magnetic brake is fitted on the main driving shaft of each leaf.

Each Ward Leonard set comprises a 35 h.p., 1,450 r.p.m., 3-phase squirrel cage motor directly coupled to a 0/22 kW, 0/440 volt D.C. generator. The motor is energised at 400 volts from the local 50-cycle supply mains, while the 230 volt D.C. supply to the generator field circuit is obtained by means of a 3-phase transformer-rectifier unit which also provides the excitation for the leaf motor and the magnetic brake solenoids.

The rear locking device on each leaf is driven through worm gearing by a 1 h.p., 1,450 r.p.m. squirrel cage motor which is connected through reversing contactors to the 400 volt, 3-phase supply. A slipping clutch is provided on the motor shaft and, in addition, a time delay relay in the contactor unit.

Traffic Control and Navigation Signals.

Traffic gates are provided at each end of the opening span and are closed by hand before the bridge is raised. Red lights mounted on each gate and bells on each approach automatically give warning to road traffic as soon as the sequence of operations for opening the bridge is initiated.

Shipping in the channel is informed of the position of the opening span by means of two solenoid-operated semaphores. These signals are mounted on masts which are erected on platforms, one on each side of the bridge, near the control cabins. In addition, four white navigation lights, two facing upstream and two downstream, are provided to indicate the extremities of the bridge opening. These lights are switched on automatically at night, there being no direct connection with the bridge system.

Control Gear.

All the control gear necessary for the operation of the bridge is installed in the two cabins adjacent to the ends of the opening span. The operation of the whole equipment is controlled from the operator's desk on the Barrow side of the bridge (Fig. 5).

Main and auxiliary isolators and fuses for the incoming supplies to the machines and to the various control and cubicle heating circuits are mounted on the Barrow control panel which also houses the main line contactor; this must be closed before any of the motors can be started. The "start" and "stop" pushbuttons which control the operation of this contactor are mounted on the desk, and, in addition, an "emergency stop" pushbutton is provided in each cabin. The starters for the driving motors of the Ward Leonard sets are of the automatic star/delta type. Both leaf motors are provided with two stage overload protection for small and heavy overloads.

The sequence of operations necessary for either raising or lowering the bridge is initiated from the desk by means of a single master controller, a "raise/lower" selector switch being provided to set the controller for the duty required. Since the positions to which the controller must be set for the various operations are not exactly the same for both duties, two sets of labels, one for the raising and one for the lowering

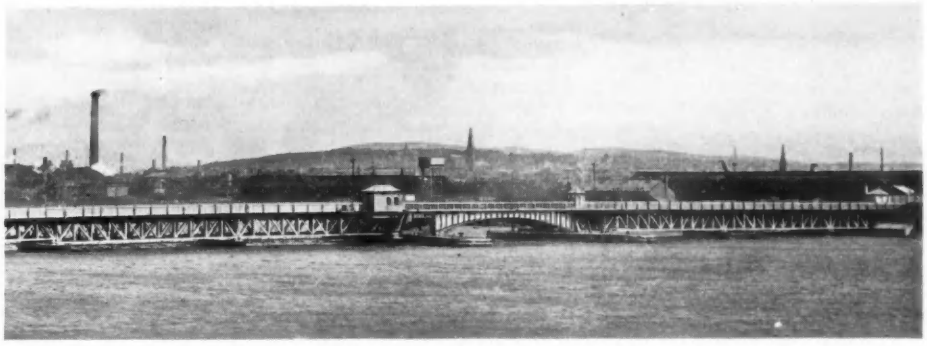


Fig. 1. General view of the Jubilee Bridge, Barrow-in-Furness, as seen from Walney Island.

Modernisation of Jubilee Bridge, Barrow-in-Furness—continued

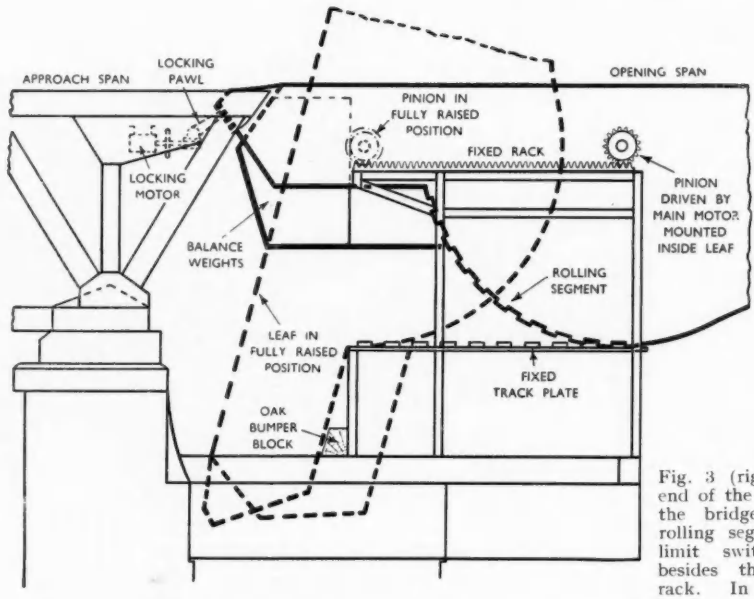


Fig. 2. Simplified drawing of the rear portion of one leaf of the opening span of the bridge, to illustrate the principle of operation by the new electrical drives.

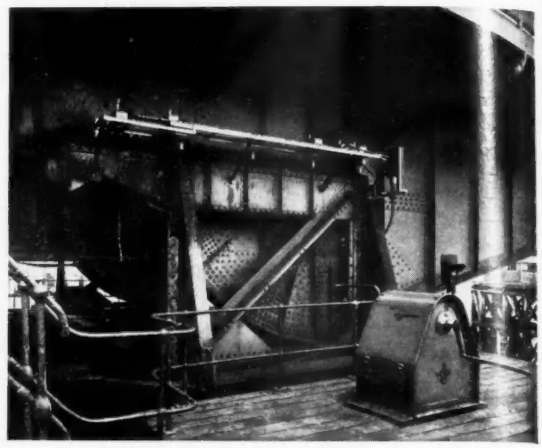


Fig. 3 (right). The rear end of the Barrow leaf of the bridge showing the rolling segments and the limit switches mounted besides the longitudinal rack. In the foreground is the emergency manual operating gear and, immediately behind it, one of the navigation lights.

sequence, are fitted behind semi-opaque "Perspex" screens and one set only is illuminated, according to the setting of the selector switch, so that only the relevant instructions are visible to the operator. A further switch is provided on the desk to select the appropriate navigation semaphore.

Once the raising or lowering sequence has been started by means of the master controller, the timing of the successive operations is regulated by a system of limit switches which also serve to operate indicating lamps on the control desk so that the operator is fully informed of the progress of the sequence in hand.

An accurate and continuous picture of the position of the leaves of the bridge is given by a position indicator mounted on the desk. This instrument, which was manufactured by Salford Electrical Instruments Ltd., consists of two moving iron voltmeter movements mounted in one case.

Cables.

The main supply is brought into the Barrow control cabin, which is connected to the cabin on the Walney Island side by four submarine cables. One length of 4-core cable carries the main A.C. supply while the connections for the auxiliary, limit switch and interlocking circuits consist of 15-core and 20-core cables.

The armature and field supplies for the leaf motors are carried from the marshalling kiosk by 4-core paper-insulated cables which terminate in special waterproof connection boxes on the ends of the fixed spans.

The connections between the marshalling kiosks and the limit switches, navigational lights, semaphores, brakes, gates and locking motors, etc., consist of 2-core, 3-core and 4-core cables. All the cables in this installation were manufactured by Pirelli-General Cable Works, Ltd.

Operation.

In order to raise the bridge, starting from the normal closed and locked position with the traffic gates open and both navigation semaphores set horizontally at "danger," the leaf motor change-over switches and the semaphore selector switch are first set to the positions required. The main selector switch is now placed in the "off" position and the "start" pushbutton is depressed, thus closing the main line contactor. The motor generator set in the Walney cabin immediately starts and runs up to speed, followed after approximately eight seconds by the Barrow set.

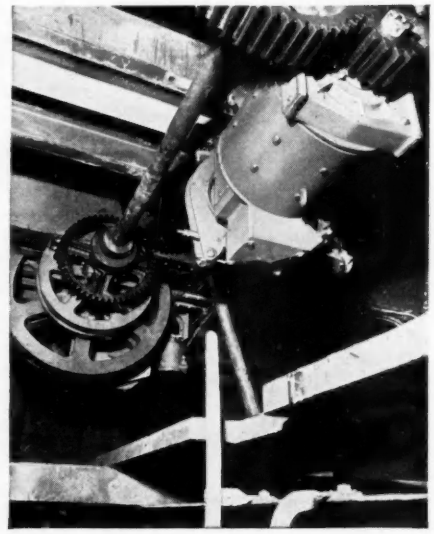


Fig. 4. The 25 h.p. main and stand-by leaf motors mounted inside the Barrow leaf of the bridge. The magnetic brakes can also be seen.

The operator next sets the main selector switch to "raise," thus illuminating the appropriate labels on the master controller, which is now moved fully over in the "raise" direction. This switches on the red lights on the traffic gates and the warning bell on each approach is sounded. When the passage of traffic over the bridge has ceased, the operators on both sides close their respective gates. Immediately both gates are fully closed, limit switches operate to stop the warning bells and to connect the supply to the locking motors which start to disengage the rear locking devices, extinguishing the "locked" indicating lamps in both cabins.

When the locking pawls on both leaves have reached the fully unlocked position, the operation of further limit switches energises the raise control relay, and through the leaf motors and their associated generators, simultaneously excited in the required direction, the leaves begin to rise at creeping speed. When they have risen through an angle of 5° an accelerating relay is energised which cuts out, step by step, a series resistor common to the field circuits of both generators, thus causing both leaf motors to accelerate until they are running at full speed. The leaves continue to rise until either one of them has risen through 69°, at which point the accelerating relay is de-energised and the motors decelerate to creeping speed.

As each leaf reaches 74°, a final limit switch operates to disconnect the leaf motor from its associated generator and to apply the brakes. When both leaves have reached the fully raised position, the selected navigation semaphore is lowered to show that the bridge is open to shipping and, at the same time, indicating lamps on the desk inform the operator that the raising operation is completed.

To close the bridge, the selector switch is set to the "lower" position, thus changing the labels of the master controller to those required for the lowering sequence. Simul-

Modernisation of Jubilee Bridge, Barrow-in-Furness—continued

taneously, the navigation semaphore begins to rise and, when both semaphores are set at "danger," a circuit is completed from the master controller through the "lower" relay. When the master controller is now moved fully over in the "lower" direction, this relay is energised and, reconnecting the generator field circuit to give reversed excitation, connects the leaf motors to their respective generators. The motors, therefore, accelerate to full speed, lowering the leaves of the bridge.

When either leaf reaches an elevation of 15°, it stops until the other leaf has reached the same elevation. Both motors then continue to run at creeping speed. The Walney leaf stops as soon as it reaches 10° elevation, the Barrow leaf continuing to fall until, at 5° elevation, it also stops. The Walney leaf now restarts and travels down until it reaches the Barrow leaf, thus engaging the interlocking extensions on the front ends of the leaves. The Barrow leaf is now restarted and both bascules are driven home. When both leaves are fully lowered, the "lower" relay is de-energised and the locking motors are started, which continue to run for about ten seconds after the limit switches on the locks have operated, thus ensuring that the pawls are fully home. Indicating lamps in both cabins are illuminated when the bridge is locked, and the operators now open their traffic gates by hand, the red gate lights being extinguished as soon as both gates are fully open. Further lamps on the desk indicate when the bridge is open to road traffic and the motor generator sets may then be shut down by pressing the "stop" pushbutton.

Fig. 5. The interior of the Barrow control cabin showing the operator's desk and the motor generator set. Through the windows the bridge may be seen in the raised position.

If necessary, the operator can control the separate stages in the operation of the bridge by moving the master controller only to the required position. If, for example, instead of turning the controller fully in the "raise" direction, he moves it only to the "unlock" position, the raising operations continue automatically until the locking pawls are fully disengaged, but nothing happens beyond this stage until the master controller is moved on. In cases of emergency, all motors can be stopped instantaneously and the brakes applied by pressing the "emergency stop" pushbutton in either cabin. The button must then be reset before operation of the bridge can recommence.

Acknowledgment.

Acknowledgment is due to Mr. J. N. Flitcroft, A.M.I.C.E., M.I.Mun.E., Borough Engineer and Surveyor of Barrow-in-Furness, for assistance in obtaining photographs of the installation and for permission to publish the above information. The whole of the electrical equipment was supplied by The General Electric Co. Ltd. The mechanical engineering was carried out by Vickers-Armstrongs, Ltd.; and the Blackburn office of W. H. Smith and Co., Electrical Engineers, Ltd., the main contractor, was responsible for the complete installation.

The Institution of Civil Engineers

On the 2nd February and 9th March respectively, the following two papers were read before members of the Institution of Civil Engineers.

"Site Exploration for Maritime and River Works" by M. J. Tomlinson, A.M.I.C.E.

The general procedure and methods for making site investigations are described in the Institution's Code of Practice for Site Investigations. The purpose of the Paper is to describe the special procedure and techniques for exploring sites for maritime and river works, and to give some examples of the effect of soil conditions on the design and construction of marine works.

The operations of positioning and anchoring boring craft are described. It is usual to adapt suitable local craft for carrying the boring equipment, rather than to use special vessels. Ore lighters, fishing drifters, salvage vessels, and "Beetle" pontoons (used to carry the floating roadways of Mulberry Harbour) have all been employed for marine borings. Where conditions permit, fixed stagings are always preferable to floating craft.

The suitability of the various methods of boring is discussed. Probing by jetting is a rapid means of filling-in data between widely spaced cased boreholes. Wash borings, using a low-pressure water flush in a small diameter cased borehole are thought to give satisfactory information, particularly when used in conjunction with the "standard" penetration test. Shell and auger borings are suitable, both for soft soils and for rock, and are essential when information on groundwater conditions is required.

The application of various types of in-situ penetration and vane tests is discussed. The cone penetration test has been found to be a useful method if exploring the thickness and consistence of alternating sand, silt, and clay layers in alluvial deposits. Comments are made on driving and loading test piles on off-shore sites.

The examples of site investigations given in the latter part of the Paper include a description of methods used to drill through a rocky sea bed, at the site of the oil and cargo jetties at Mina al-Ahmadi. A comparison is made between the results of the borings and the driving of the permanent piles. A similar comparison is made between borings, soil tests, and the driving of test piles on a harbour site in Syria. The problems of foundation design, and attack by river water on steel, concrete, and timber structures are discussed in connection with an ore-loading pier in Sierra Leone. The use of a rotary diamond core drill to investigate the stability of coastal cliffs at Cullercoats is described.

"Design and Construction of a Prestressed Concrete Framed Transit Shed for the Port of London Authority" by N. N. B. Ordman, B.Sc., A.M.I.C.E., and I. S. S. Greeves, A.M.I.C.E.

The project described in the Paper is part of the post-war reconstruction programme being undertaken by the Port of London Authority. It represents the first use by the authority of prestressed concrete, and illustrates a number of aspects of current practice in the planning of transit berths.

The warehouses occupying the berths were destroyed by enemy bombing, and the decision to redevelop the berth for transit operations raised a number of difficulties because of site limitations and levels. Parts of the vaults which formed the basements of the bombed warehouses were incorporated in the reinforced concrete sub-structure of the new building. The quay deck which had been totally destroyed was rebuilt to modern requirements, and the damaged quay wall was repaired in a simple but effective fashion.

The transit shed, which is 150-ft. wide with a floor area of approximately 32,000 square feet, is framed with prestressed concrete three-pin portals. The decision to use prestressed concrete was based on the desire to obtain experience of this form of construction and to save steel—which was, at the time of construction, in short supply. The design lent itself to precasting and the main units were cast and post-tensioned on site. The purlins and sheeting rails, which were pre-tensioned, were factory made on the long-line system. The shed is clad in aluminium sheeting.

The cost of prestressed concrete as compared with other media is discussed, and the difficulties encountered are described together with the means used to overcome them.

The Council of The Institution of Civil Engineers announce that they have appointed Mr. Alexander McDonald, B.Sc., M.I.C.E., to the position of Secretary of the Institution, to succeed Mr. E. Graham Clark, C.B.E., M.C., M.Sc., M.I.C.E., who will be retiring this year.

Manufacturers' Announcements

Dock Lighting keeps Cargoes Moving

Timber stacks at No. 9 Dock of the Manchester Ship Canal cause problems for the lighting engineer. The length of these stacks and the need for space to manoeuvre big loading vehicles make it impossible to erect enough columns for low-powered light sources to be effective. Since the total area is 1,500-ft. by 500-ft. side lighting is not satisfactory either.

The system adopted uses only 13 concrete columns sited in two rows at 250-ft. intervals each carrying a platform 5-ft. square at a height of 40-ft. On each platform are mounted four 400w. mercury

Day and Night Views of No. 9 Dock, Manchester.

floodlights. Their design is based on the G.E.C. " apron " floodlight for airport lighting, giving a beam of about 100° spread in azimuth with a narrow vertical divergence. The four floodlights thus light through 360°.

These floodlights are particularly suited to the conditions of the Ship Canal area, since they are " dirt-tight " and are fitted with silvered glass reflectors. The reflectors are coppered and lead backed by a process evolved for the lighting industry. This enables them to withstand both the heat from the lamps and industrial atmospheric conditions.

Grouping four units on a common platform with an access ladder makes maintenance easy in an area where a tower wagon would be inconvenient.

The installation was designed by the Electrical Engineering Section of the Manchester Ship Canal Company Ltd., working with the lighting engineers of the General Electric Co., Ltd., and was installed by S. Dickinson, Ltd.

Chlorobromomethane Fire Extinguisher

Nu-Swift Ltd., the fire extinguisher manufacturers, announce the marketing by them of a new and revolutionary type of pressure-operated extinguisher in which chlorobromomethane, the new fire fighting chemical, is held with absorbed carbon dioxide under constant pressure.

This is claimed to be the first British made extinguisher in which use is made of the extraordinary fire fighting properties of chlorobromomethane and details are given of tests carried out on a petrol fire two square feet in size on which an old-fashioned quart size Nu-Swift hand pump holding carbon tetrachloride, after 40 seconds pumping failed to extinguish the fire, while the pressure-operated Chlorobromomethane Extinguisher, of the same size, put out a similar fire in 1½ seconds.

The scientific explanation of this extraordinary increase in fire fighting power is the low inhibitory factor of chlorobromomethane compared with that of other chemicals in commercial production, while another important factor is the thorough atomisation of chlorobromomethane by the carbon dioxide.

Stated to be particularly effective on extra hazardous risks, such as all electrical equipment like radar, neon signs, television equipment, switchgear, etc. and medium-sized organic solvent fires of all types common in laboratories, garages, etc., this extra rapid extinguisher, less than 16 inches high, is marketed by Nu-Swift Ltd. under the registered trade name of " Chloro-Flash."

For use in the home market, " Chloro-Flash " Model 2003 has been approved by the Fire Offices' Committee, but a large export market is also expected. The sealed pressurized charge makes this type of extinguisher particularly suitable for use in the tropics while also effective at arctic temperatures as chlorobromomethane freezes only at −120°F. (−86°C.).

SITUATIONS VACANT.

PLANNING ENGINEER, aged 30-35, with varied site experience of heavy civil engineering, preferably with a contractor, required for Head Office. Write, giving details of education and experience, to George Wimpey & Co., Ltd. (Planning Dept.), 27, Hammersmith Grove, London, W.6.

THE BOARD OF TRUSTEES OF THE PORT OF ADEN require the services of a Secretary (Male) of British nationality. He should possess wide experience of Port and Harbour administration including, in particular, wharf and port rating, staff administration and general office routine. He should be capable of handling all routine Port and Harbour affairs and of preparing memoranda for submission to the Trustees as required. Some legal knowledge would be an advantage. Salary £1,500 per annum rising to £1,900, with annual increments of £50. The starting salary within the scale to be in accordance with qualifications and experience. Free passages out and home. Unfurnished quarters available at rental not exceeding 10% of salary. Basic furniture can be hired from Port Trust on reasonable terms. Free medical attention provided. If admitted to Board's permanent establishment the Secretary will be subject to Port Trust leave and passage regulations, also Contributory Pension Fund Rules. Form of application obtainable from Consulting Engineers & Agents, Aden Port Trust, 1 Lygon Place, Grosvenor Gardens, London, S.W.1.

FOR SALE

OVERHEAD RUN-WAY WEIGHER. Capacity chart 500 lbs. x 8 ozs. Tare 250 lbs. x 8 ozs. Cine-projector indicator. In original cases as delivered by W. & T. Avery Ltd. Will be adapted if necessary by makers to suit individual requirements. Cost £340. Offers invited. Box 156, " Dock & Harbour Authority," 19, Harcourt Street, London, W.1.

THREE HIBBERD " PLANET " DIESEL LOCOS, 20/26 B.H.P., 24 inch gauge. New 1949, guaranteed and in first class condition. Hudson 2 C.Y.V. Tupe side tipping skips. 24 inch gauge. Have had little use—very good order. Apply Box No. 155, " Dock & Harbour Authority," 19, Harcourt Street, London, W.1.

PONTOON DOCK FOR SALE.

Aberdeen Harbour Commissioners invite offers for their No. 1 Pontoon Dock, complete with shore fixings, as it lies at present at moorings at Albert Quay.

This single sided dock built in 1900 of wrought iron is 146′ 0″ long (121′ 0″ over blocks), 22 feet wide, has a depth of 15 feet over blocks and a designed lifting capacity of 415 tons. The deadweight of the dock is approximately 300 tons plus weight of machinery fittings and timber.

The dock is in use at present but is being replaced by a larger one and will be available to the purchaser later this year.

Offers, in sealed envelope endorsed " Pontoon Dock No. 1 ", should be lodged not later than 26th May, 1954, with the Harbour Engineer, 15 Regent Quay, Aberdeen, from whom further particulars may be obtained.

For sale :

Complete electric

CUTTER SUCTION DREDGER

Cutter depth 25 ft.; Pump 275 H.P.; Cutter 80 H.P. dim. 66′ 8″ × 17′ × 7′ 4″. Specially constructed for transport by ship. Write to box 154, " Dock and Harbour Authority," 19, Harcourt Street, W.1.